EDUCATION AND SECURITY: DESIGN AND EVALUATION TOOLS FOR DELIBERATE DISEASE RISKS MITIGATION

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Abstract

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Keywords: Biological weapons, biorisk, BTWC, securitization, biosecurity, education, training, constructivism.

This thesis addresses the role of education to mitigate the risks of deliberate disease, including biological weapons. Specifically, it aims to analyse how education was constructed as a potential instrument to mitigate specific security risks; if and how education could impact on risks; and how effectiveness of education as a risk mitigation measure could be improved. The research framework combines concepts of security, risk and education within a general constructionist approach. Securitization is used to analyse attempts to construct education as a tool to mitigate specific security risks; risk assessment is used to identify and characterize risk scenarios and potential for risks mitigation; and instructional design and evaluation models are used for the design and evaluation of education. The thesis contends that education has been constructed as a mitigation tool for what were presented as urgent security risks of deliberate disease. Nine attempted securitization moves are identified and assessed. Improved competences identified in four thematic areas, and built with education, can mitigate risks in specific scenarios via impacting factors that primarily influence risk likelihood. The thesis presents several examples of achieved learning objectives, and tools that can be useful to evaluate behavioural and risk impacts, though empirical results on these levels here are still scarce. Design and evaluation tools, illustrated through a large amount of original and pre-existing data from a range of countries and contexts, are presented that can improve effectiveness of education as a deliberate disease risks mitigation measure.

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Table of Contents

List of Tables

Abbreviations

AAAS	American Association for the Advancement of Science
ADDIE	Analysis, Design, Development, Implementation and Evaluation
AHG	Ad-Hoc Group of the States Parties to the Biological and Toxin Weapons Convention
AMBS	Association Marocaine de Biosécurité
AMP	Assessment Mitigation Performance
ASTD	American Association for Training Development
BDRC	Bradford Disarmament Research Centre
BEP	Biosecurity Engagement Program (United States)
QAU	Quaid-i-Azam University (Pakistan)
BOD	Behavioural Observation Data
BRCs	Biological Resource Centres
BRM	Biorisk Management
BTWC	Biological and Toxin Weapons Convention
BW	Biological Weapons
CBMs	Confidence Building Measures
CBRN	Chemical, Biological, Radiological and Nuclear
CBW	Chemical and Biological Weapons
cDNA	Complementary Deoxyribonucleic Acid
CoE	Centres of Excellence
CRDF	Civilian Research and Development Foundation
CTBTO	Comprehensive Test Ban Treaty Organisation
CW	Chemical Weapons
CWC	Chemical Weapons Convention
DNA	Deoxyribonucleic Acid
DURC	Dual-use Research of Concern
ECTS	European Credit Transfer System
EMBO	European Molecular Biology Organisation
EMR	Educational Module Resource
ERA	Emerging and Readily Available
EU	European Union
EUBARNet	European Biosecurity Awareness Raising Network
FAO	United Nations Food and Agriculture Organisation
FBI	Federal Bureau of Investigations (United States)
G8GP	G8 Global Partnership Against the Spread of Weapons and Materials of Mass Destruction
GBRMC	Global Biorisk Management Curriculum
GMO	Genetically Modified Organisms
HEI	Higher Education Institution
IAEA	International Atomic Energy Agency
IASB	International Association of Synthetic Biology
IBCTR	International Biological and Chemical Threat Reduction
ICGEB	United Nations International Centre for Genetic Engineering and Biotechnology
ILO	Intended Learning Outcome
INES	International Network of Engineers and Scientists for Global Responsibility
INSEN	International Nuclear Security Education Network
IRGC	International Risk Governance Council

IPISD	Interservice Procedures for Instructional Systems Development
ISD	Instructional Systems Design
ISEC	Prevention of and Fight Against Crime Programme (European Union)
ISIS	Euro-Mediterranean Master in Neuroscience and Biotechnology
ISP	Inter-Sessional Process of the Biological and Toxin Weapons Convention
IUPAC	International Union of Pure and Applied Chemistry
LAI	Laboratory-acquired Infections
LMS	Learning Management System
LNCV	Landau Network – Centro Volta
MCDA	Multi-Criteria Decision Analysis
NGO	Non-Governmental Organisation
NSABB	National Science Advisory Board for Biosecurity (United States)
OECD	Organisation for Economic Co-Operation and Development
OPCW	Organisation for the Prohibition of Chemical Weapons
PPE	Personal Protective Equipment
PRA	Probabilistic Risk Assessment
QRA	Quantitative Risk Assessment
SAI	Standing Agenda Item of the Biological and Toxin Weapons Convention Inter-Sessional Process
SARS	Severe Acute Respiratory Syndrome
SESAME	Synchrotron-light for Experimental Science and Applications in the Middle East
ABACC	Agência Brasileiro-Argentina de Contabilidade e Controle de Materiais Nucleares
SOP	Standard Operating Procedure
TBL	Team-Based Learning
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICRI	United Nations Interregional Crime Research Institute
UNMOVIC	United Nations Monitoring, Verification and Inspection Commission
UNSC	United Nations Security Council
UNSCOM	United Nations Special Commission
USAMRIID	United States Army Medical Research Institute of Infectious Diseases
USSR	Union of Soviet Socialist Republics
VEREX	Ad Hoc Group of Governmental Experts to Identify and Examine Potential Verification Measures from a Scientific and Technical Standpoint (Biological and Toxin Weapons Convention)
WHO	World Health Organisation
WMD	Weapons of Mass Destruction

1. Introduction & Methodology

1.1 Introduction

Life and health-related sciences and technologies continue to advance and provide significant benefits globally in terms of health, economic growth and quality of life. At the same time, the potential for harm arising from hazards in these fields also exists. While this may be true for virtually any area of human endeavour, the potential damages connected with misuse in these fields have been described, in the last few decades and the evolving global context, as particularly pressing. Some concerns focused on toxins or infectious microorganisms, and their potential for harm described in terms of "risks". This thesis presents a critical analysis, in the broader context of those risks, of the risks of deliberate disease, or that sciences and technologies are intentionally exploited and misused to cause disease. Capacity building for people with technical roles and, within that rubric, "education" of young and future scientists and practitioners, has been indicated as a possible useful measure to mitigate the risks of deliberate disease. However, to date it is not clear if, why and how exactly education became a potential measure in an arena traditionally focused on "security"; how the mitigation potential of education could be assessed; and, in case risk mitigation through education is possible, how could education be designed in ways that maximize mitigation, and its effects evaluated. This complex is the research problem addressed by this thesis, which will be explored by trying to answer three research questions.

1.2 Research questions

Research question 1: how was education constructed as a measure to mitigate the security risks of deliberate disease?

The identification of the role of education into mitigation strategies for deliberate disease risks will be analysed and discussed basing on the evolution of policy and scientific discourses.

Research question 2: how could education mitigate risks of deliberate disease?

As it will be discussed, it would be unfair to expect education to be a silver bullet for addressing those concerns, but it is interesting to investigate the potential mechanisms in which education could influence deliberate disease risks.

> *Research question 3: what would the tools be to improve effectiveness of education as a mitigation measure of risks of deliberate disease?*

Without claiming a generally applicable meaning for the concept of "effectiveness", how the attribute is interpreted in this thesis for the third research question is education that can be relevant, generalized and sustained. With relevant, I mean that it generates capacities that contribute to the objective of risk mitigation; with generalized, that is taken by all those who may have a role in mitigating those risks; and with sustained that it is repeated over time to all those who acquire those roles and have those responsibilities.

1.3 Research framework

This research constructs and employs a framework to tackle the above research questions, mobilizing and connecting resources from three conceptual areas: security, risk and learning. These areas are not independent from each other, but rather interact and are mutually influenced through complex, yet hopefully clearly described, relationships. The theoretical background and models are described in more detail in the next Chapter, however here I present a summary of the three conceptual areas and of their interactions.

The security conceptual area intervenes in the research framework in relation to the conceptualizations around security and disease, security and risk, and security and education. The securitization approach is used as a lens to investigate the role of education in security risk mitigation, as well as the how and the why of the construction of such role. The conceptual area of risk intervenes to identify and justify specific patterns in which education has the potential to mitigate the risks of deliberate disease. Risk assessment and risk management approaches are used to identify what are we talking about when we talk of "deliberate disease risks"; discuss what may constitute those risks; what exactly would "mitigation" mean; and if, how and what education has the potential to mitigate those risks. The conceptual area of learning intervenes to identify and discuss features of education that have the potential to mitigate deliberate disease risks. Instructional design and evaluation approaches are used to present and test practical aspects of education.

While these three main areas are not unequivocally matched with the three research questions, in the research framework the conceptual area of security is primarily used to address the first question; the conceptual area of risk is primarily used to address the second question; and the conceptual area of learning is primarily used to address the third question. Combining these conceptual areas, the thesis aims at providing insights on the role of education as an instrument to mitigate the security risks of deliberate disease, and on design and evaluation tools for such education. After a detailed discussion on the theoretical framework underpinning the research in the next Chapter, the thesis firstly will identify the dimensions of deliberate disease risks in Chapter 3; secondly analyse the securitization of education as a possible risk mitigation measure for these risks in Chapter 4; and thirdly apply science of learning models to design and evaluate education as a deliberate disease risks mitigation measure in Chapters 5 to 9. Two main models are leveraged from educational science, one on instructional systems design and one on evaluation of the impact of education. Both models are applied on two plans that I call “education” and “instruction design”. The former focuses on design and evaluation of education to mitigate deliberate disease risks, in which the target and the audience of interventions are future and young scientists and practitioners. The latter focuses on design and evaluation of instruction for educators of those future and young scientists and practitioners that, as I will argue in the thesis, is one factor to facilitate the “sustained” component of “effectiveness” of education. Applying these models, I will present design and evaluation tools for both plans of research, however they should not be considered as disconnected. The instruction design plan is somehow consequential to the education plan[1] as we move from discussing the second to the third research question. Furthermore, implementation under each plan is connected to certain levels of evaluation, as will be explained

[1] If and once it should be realized that education does offer risk mitigation potential.

in the next Chapter; evaluation of outcomes applying the design and evaluation tools developed in the thesis is done against the risks characterized in Chapter 3; and how those design and evaluation tools could be applied, their opportunities and limitations, are discussed in the light of the role of education as a security measure argued in Chapter 4. This is how the different areas of the research framework come together; crossing and in common to the whole research approach there is a general (weak) constructionist approach that I keep as a researcher. In the next Chapter I explain in more detail how such an approach is compatible with the models I use and indeed how features of constructionism can be related even to those aspects (such as from the risk management and educational science areas) that may almost appear of a positivistic style. This stance leads to specific ontological and epistemological considerations that are thoroughly discussed in the next Chapter, however the research design also influences methodology (as well as ontology, epistemology and methodology influencing each other), which is reflected on the range and mixture of data collection and analysis methods used in the research. Before presenting those data and methods, and due to their very nature, however, it's important that I tell how I became involved in the subject researched, and clarify my role as researcher.

1.4 Genesis of the research and the role of the author

This research was carried in the course of a part-time, extramural PhD programme I followed between 2011 and 2016. In the meanwhile, I was working as analyst and project officer, at the international non-governmental organization Landau Network-Centro Volta based in Italy until 2012 and at the Sandia National Laboratories in the US between 2013 and 2015. This situation meant that the research was carried in parallel but also in connection to my professional career, which led me to become familiar with, and actually contribute to, policy discussions and implementation of actions on biosafety and biosecurity; biological weapons non-proliferation; the work of the BTWC and other processes; risk assessment and management of deliberate, accidental and natural disease risks; and capacity building on those risks in many countries and contexts, but particularly in higher education. The situation also allowed me to develop a broad and deep picture regarding education, security and risk mitigation. My first involvement in the subject was when I designed and coordinated a project titled “Fostering the Biosecurity Norm”, implemented in 2008-2009 by LNCV and the University of Bradford.[2] That experience suggested to me and other colleagues in Italy, the UK and elsewhere that the space, and indeed the need, existed for an academic analysis on education as a tool to mitigate the security risks of deliberate disease, which could go beyond and deeper than the mere implementation of projects responding to policy programmes and decisions. Hence, further projects funded by research grants or commissioned by governmental agencies in which I was involved since 2011 have been also considered in the light of the questions posed by this research. Furthermore, in my professional capacity I attended BTWC Meetings of Experts and/or Meetings of States Parties each year between 2007 and 2011, including those in 2008 when education and awareness raising were one of the specific topics of discussion, and the 7th Review Conference; meetings of the G8GP between 2009 and 2012 discussing scientists engagement, capacity building and education as possible means to reduce risks of misuse of science and technology; meetings of the European Commission’s Task Force on a CBRN Action Plan in 2008; and over thirty workshops and conferences between 2008 and 2013 organized by governmental, non-governmental and academic organizations in several countries on engagement of scientists on CBRN security risks issues and specifically on education and awareness raising on, and to mitigate, biorisks. While this situation opened many opportunities that I believe contributed to the originality and significance of the research, it also influenced the implementation of the research and exposed a series of criticalities.

1.4.1 Opportunities and challenges of the research situation

The main challenges consisted in: the time span of research data; timing of data collection in the research process; the influence of projects’ objectives on research; the lack of detachment of the author; and the control by the author on research data and methods. Each challenge led

[2] The project was co-funded by the Prevention of and Fight Against Crime (ISEC) programme of the European Commission. Project number EU JSL/2008/ISEC/AG/088

to decisions on if, why and how to include data; I address and discuss these challenges as justifications for inclusion can be argued.

Data included in the research was collected between 2011 and 2015; previous relevant data is considered as literature. I decided to include research data (from two of the projects introduced below) analysed while I had just started the Post-Graduate Research (PGR) school in Bradford because they were particularly relevant for the research; allowed to extend the time window where to observe developments, as the same contexts were then observed by data collected in the following years and by other collection methods created specifically and exclusively for this research; they deserved additional and deeper analyses than the often narrow consideration in their specific projects and were not previously published; they allowed novel considerations and analyses when considered together with data from other countries and projects; they were collected with robust research methods, as they were based on, and improved, previous research efforts, were based on my pre-existing policy research expertise, and were consistent with research methods that were reviewed and approved during the PGR school at the University; and also to make a rather arbitrary boundary between literature and original arguments coinciding with the year when I started my PhD journey.

Regarding the timing of data collection in the research process, collecting data that would be useful for this research often could not follow the order of research design that many PhD researches use, of hypotheses development, design of data gathering methods, data gathering, and data analysis. Rather, data gathering methods and data collection depended on the timing of projects that I was involved in, which was often exogenous. This meant, between 2011 and 2015, often going back, reviewing and improving consecutive versions of the same data collection tools as they were applied to new projects; as well as refining, confirming, changing and adding to research assumptions, findings and questions. On the other hand, the collection tools for the data considered in this research maintained common features that, I think, allow considering them together and most importantly to transversally apply the models for developing possible design and evaluation tools for education as security risks mitigation that are proposed in the thesis.

A third criticality regards the relationship and indeed the independence between this research and the projects from which some of the data and observations are included. The projects had their own priorities, goals and objectives in line with the specific programmes, and funders, to which they were responding. The choice of countries, for example, was opportunistic as depending on those available from projects. Even if parts of the data discussed in the research were originally collected for other projects, however, I have reviewed them to select what was relevant for my specific research problem and looked at them under an entirely original light, so that they could provide new insights when overviewed together and used to develop or test novel design and evaluation tools. Furthermore, data from projects were used in compliance with data management rules of the same projects; based on the indication to participants that they could be used for the project as well as for other academic work; with the authorization of the coordinating organizations' management; and/or with anonymisation of details of individuals, organizations or countries, depending on the case. Finally, data from projects were complemented with entirely new data, collected for the exclusive purpose of this PhD research, that are particularly important for the original contribution of the thesis.[3]

The fourth challenge is the potential lack of detachment of the author. This is a clear issue with a topic and processes in which I, as a researcher, am not only familiar but also, to some extent, embedded. Considering that part of this research is an analysis of the securitization of education as a measure to mitigate the security risks of deliberate disease, the doubt for example arises if I am not contributing (or did not contribute) to the same securitization that I am studying. While this is somehow inevitable given my situation, firstly it should be considered that I was never a "decision-maker" on the subject but rather an implementer; and secondly that I did include measures to mitigate the risk of bias. The selected analytical tools

[3] In particular interviews to describe and test evaluation tools in the education and instruction design plans of research.

were chosen to provide a variety of perspectives on the same issues; the same tools were selected to enhance objectivity, for example mixing quantitative and qualitative data; and most of the data analysis and the thesis write-up was conducted during October 2015 and June 2016, during a largely sabbatical period from my professional roles in order to focus on the research and regain some detachment.

The fifth and final criticality is the control by the author on research data and collection methods. While this is not a problem for the data that was collected entirely and exclusively for the PhD, it could be relevant for those observed from other projects. In most cases I both designed and implemented data collection, keeping full control on the whole process. In some cases, I collaborated with colleagues and partners to design data collection tools, but data was materially collected and tabulated by others closer to participants or respondents. In other cases I include data I collected using tools and methods designed by others, as explained and credited below, that were particularly useful to shed new light or could be analysed in new ways to develop design and evaluation tools.

1.5 Significance of the research

Notwithstanding the above challenges, I think this research is significant and has the potential to make a relevant original contribution to knowledge about education as an instrument to mitigate security risks of deliberate disease. While projects and publications addressed before the topic of education and training on risks, security risks, and biosecurity risks, there has not been a structured analysis on the role attributed to education as a security tool in a security arena, and on how the construction of this role happened. This is the first area where this research hopes to provide a significant contribution.

Furthermore, several projects have been carried in different contexts and by different actors (including some from which data is observed here), however analyses that merged and compared different experiences, data sets and data tools are scarce. Individual capacity building projects, furthermore, focus on completing their tasks and delivering products, often rather than investigating the deeper meanings, reasons and trends in capacity building regarding these risks. At the same time, they often collect large amounts of data that may allow such subsequent investigations. This supports the need for a different, more structured, robust academic analysis that can go beyond just training implementation. This thesis designs and employs a research framework suggesting to connect outcomes in terms of learning to outcomes in terms of security risks. In doing so, it proposes some tools, based on the experiences that contributed to that research framework, to design and evaluate education that could be effective as a measure to mitigate the security risks of deliberate disease. This is a second area where this research hopes to provide a significant contribution.

The above design and evaluation tools are based and tested on a large amount of data presented in the research, with both data collected and analysed specifically and exclusively for this research, and data observed from projects pre-existing or independent to the research, including original data. Furthermore, originality should be looked for not only regarding data but also and possibly more importantly on exercising "independent critical thought" (Silverman, 2005 p. 70). The amount of data; the consideration of these data sets together; the range of contexts they illustrate;[4] the time window embraced by analyses for phenomena related to capacity building that are often long-term and may be challenging to observe with a "normal" PhD plan; the research framework based on the three conceptual areas and their interconnections; and the specific models applied to develop design and evaluation tools, represent occasions for originality, novelty and significance of this research.

1.5.1 Published work

Some of the work presented in this thesis has been published between 2011 and 2015 by myself or in work co-authored with colleagues in relation to specific projects, even if this dissertation is the first occasion in which data is presented together. Parts of the results of the questionnaire

[4] No claim of generalizability is included among these reasons for the significance of the research. As further discussed below, data is not generalized to any larger population than the groups and samples it is collected from. Nonetheless, the research represents an opportunity to discuss original data, or existing data in new ways, for an illustrative picture of information, examples and trends in many contexts; and to develop and operationalize the proposed design and evaluation tools for education as a potential risk mitigation measure.

from the Pakistan project was included in a booklet published in 2011 (Shinwari et al., 2011). Experiences from the EUBARNet project were discussed by Revill et al. (2012), Mancini and Fasani (Mancini and Fasani, 2012a; 2012b), and Mancini (Mancini, 2012b; 2012a). Results of that project were also used to discuss the value of collaborative and active learning methods for education on biosecurity risks (Novossiolova et al., 2013). A paper on security and misuse risks in neurosciences, responsibility of scientists and the role of higher education was presented in a conference (Mancini et al., 2012). Finally, a version of parts of Chapter 3 on the dimensions of the risks of deliberate disease constituted a book chapter (Mancini, 2015).

1.6 Focus on higher education

The research focuses on one particular context for education as a potential deliberate disease risks mitigation tool, which is pre-service in the framework of higher education in the life and connected sciences and technologies sectors. Clearly "education" could comprise a range of capacity building actions targeting different learners in different contexts, from primary to secondary and tertiary instruction, to vocational training, continuous professional training, adult learning and redirection/reemployment of professionals. Reasons for focusing on higher education firstly include that, as discussed in detail in Chapter 4, securitization moves often identified higher education as one specific venue for proposed measures.[5] Other reasons can be both causes of the attention on higher education, and general considerations on the effectiveness potential of this educational channel. Higher education students constitute the next generation of scientists, professionals and managers.[6] Targeting this population could contribute to the formation of technically and socially informed and responsible professionals on risks related to their professions, including deliberate disease risks. Secondly, educating students during their degrees would expose them to concepts early on, increasing the probability of capacity retention. Thirdly, if they already have foundational knowledge and skills, they will be more likely to

[5] Hence a serious analysis on how that could be done, and what impacts it could have, is particularly relevant.

[6] They may also be referred to as "pre-service" to denote they have not yet entered the job market.

apply it as soon as they start working, as well as to look for additional information because they are aware of what they need to know. Fourthly, educating them on risks at the same time of, and embedded with, technical education, will facilitate integration of safety and security rather than they being “adds-on” to technical capacities. Fifthly, students may have more time and be more receptive to learning than more adult learners who come back to studying during their career.

Higher education students could be targeted with actions in a range of formal and informal contexts. However, the first one to consider would be Higher Education Institutions (HEIs) providing formal post-secondary education.[7] Reasons to work with HEIs include that education is already their principal mandate.[8] Second, education in HEIs is formalized in curricula and degree programs which are imparted year after year to different cohorts of students, and that last beyond individual educators who deliver them, contributing to diachronic sustainability. Third, education in HEIs would reach large numbers of students at the same time, with a range of potential future work careers, making sure that at least foundational capacity is widely spread and synchronically sustainable over several sectors.[9]

1.7 Data description

1.7.1 Projects

This section describes the projects considered in this research from which pre-existing data was observed, besides data collected specifically and exclusively for the research. Most projects used a common set of data

[7] HEIs include universities but also polytechnics, research centres and other denominations as long as they provide higher education.

[8] Which should make easier for them to introduce new topics of instruction, or review existing ones, and would require less investment in terms of time, funding or human resources with respect to institutes that sometimes do not have established training programs or trainers.

[9] Given the identification of higher education students as learner population, and of HEIs as the primary educational context for the research focus, there are some assumptions and differences with in-service education and training to consider. Firstly, pre-service students, for example, have different background, prerequisites, experience as well as less or not yet defined job tasks than professionals. Secondly, education content will be more basic and more generic than it would for professional learners: this may mean basic information applicable to a variety of sectors. Furthermore, the structured educational environments in HEIs may determine both opportunities and limits of educational actions. These points will be discussed in more details in Chapter 5 and 6.

collection tools, which allows analysing and interpreting data with the common research framework and analytical models mentioned above. Furthermore, all these experiences of promoting capacity can be described (and in many cases have been designed) with the instructional design models that are utilized along with this research.

In 2010-2011, a project on university engagement on biosafety and biosecurity education[10] was implemented by LNCV in partnership with a biosafety association in Morocco (Association Marocaine de Biosécurité, AMBS). The project included a questionnaire survey for educators and a workshop with representatives from several HEIs.[11] In the thesis this project is referred to as “Morocco”. A similar project was implemented in the same time frame in Pakistan by LNCV in partnership with Quaid-i-Azam University (QAU) of Islamabad. The project included a questionnaire survey on life sciences and technology students in various universities; a workshop on biosafety and biosecurity for faculty members in Islamabad; and an educational seminar for students in Islamabad.[12] In the thesis this project is referred to as “Pakistan”.

Some of the European universities who had been engaged by the 2008-2009 project “Fostering the Biosecurity Norm” (Mancini and Revill, 2008; Mancini and Revill, 2009; Margalho, 2009; EFE, 2009) and remained interested in promoting biosafety and biosecurity education, became

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[10] The project was funded by the Biosecurity Engagement Program (BEP) of the United States Department of State.

[11] The questionnaire was designed based on the model described below in cooperation with AMBS, administered by members of AMBS in each university via email and in-person interviews and surveyed 227 professors and lecturers of biosciences in thirteen Moroccan universities in 2011. I tabulated the data from the original questionnaires with the help of research assistants and analysed them in cooperation with AMBS.

[12] The questionnaire was designed on the model described below in cooperation with QAU, administered in 2011 by local research students via paper questionnaires, and surveyed 448 students from 24 universities in Pakistan (Shinwari et al., 2011). I tabulated the data from the original questionnaires with the help of research assistants and analysed them in cooperation with QAU. Twelve life sciences and technology students from one university in Pakistan attended in 2011 a one-day educational seminar on deliberate disease risks that I facilitated based on instructional materials from the Educational Module Resource (ERM) developed by the University of Bradford in collaboration with LNCV and the National Defence Medical College in Japan; the seminar included a post-instruction questionnaire for students.

partners in a project I coordinated between 2011 and 2012: the European Biosecurity Awareness Raising Network (EUBARNet)[13]. Among other tasks, the project included an online investigation on considerations given on biosafety and biosecurity risks in published syllabi and course materials in HEIs in seven EU countries; and seven educational seminars for students.[14] In the thesis this project is referred to as "EUBARNet".

The ISIS Euro-Mediterranean Master in Neuroscience and Biotechnology is both a project and a graduate degree designed, developed and implemented since 2012 by a Consortium of eleven universities,[15] funded by the European TEMPUS program and coordinated by the Université de Bordeaux.[16] The engagement of myself and LNCV by a member university which had been involved in the previous "Fostering the Biosecurity Norm" and "EUBARNet" projects led the Consortium to include a module on biosecurity and dual use within the course on Bioethics, Regulations and Laws during the drafting of the Master syllabus.[17] In collaboration with University of Bradford's experts, I designed and taught 25 Master students

[13] The project was co-funded by the Prevention of and Fight Against Crime Programme (ISEC) of the European Commission; project number HOME/2010/ISEC/AG/CBRN-001. See www.eubarnet.eu for more information.

[14] The countries included Italy, the Netherlands, Poland, Portugal, Spain, Sweden and the UK. I designed the online investigation protocol, based on the model described below, and carried out it in 2011 with the support of researchers in LNCV and Bradford, analysing 184 degree courses. I directly co-facilitated six out of the seven educational seminars, that reached 268 students in seven HEIs in six EU countries (according to signed attendance lists). Returned post-instruction questionnaires were lower. University of Coimbra, Portugal (27 April 2012, 20 students/9 post-instruction questionnaire respondents), University of Milan, Italy (10 May 2012, 39 students/39 post-instruction questionnaire respondents), University of Turin, Italy (11 May 2012, 16 students/ 16 post-instruction questionnaire respondents), University of Uppsala, Sweden (31 May 2012, 30 students/no post-instruction questionnaire respondents), Delft University of Technology, the Netherlands (15 June 2012, 24 students/15 post-instruction questionnaire respondents), University of Granada, Spain (21 November 2012, 109 students/101 post-instruction questionnaire respondents), and University of Bradford, UK (21 November 2012, 30 students/30 post-instruction questionnaire respondents). About three-quarters of the EUBARNet students completing post-instruction questionnaires were undergraduate, 10% was graduate Master students and just two were PhD students. In case of mixed classes this was assessed through a specific question in the survey, while in the cases the whole class was from the same cohort the author computed it.

[15] In Morocco, Egypt, Lebanon, France, Spain and Italy.

[16] See http://isis-master.org/ for more information

[17] The module amounted to one ECTS academic credit out of three credits of the course.

the distance-learning module during the 2011-2012 academic year. In the thesis this project is referred to as “ISIS Master”.

The International Network of Universities and Institutes to Raise Awareness about Dual Use in Biotechnology was a project coordinated by LNVC in 2013-2014 that consortiated seventeen HEIs in fourteen countries.[18] Among other tasks, the project included a questionnaire survey on higher education professors in participating countries; educational seminars for university students; and workshops with faculty to share experiences among the network.[19] I contributed to the project design

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[18] The project was funded by the CBRN Risk Mitigation Centers of Excellence (CoE) initiative of the European Union under the implementation of the United Nations Interregional Crime Research Institute (UNICRI). The Consortium included Landau Network-Centro Volta, Italy (Coordinator), Agrarian University of Georgia, Georgia, Royal Scientific Society, Jordan, Middle East Scientific Institute for Security, Jordan, National Council for Scientific Research, Lebanon, National Center of Public Health, Moldova, University Mohamed V – Agdal, Morocco, Faculty of Sciences of Tétouan, Abdelmalek Essaadi University, Morocco, Quaid-i-Azam University of Islamabad, Pakistan, College of Medicine at University of the Philippines Manila, Philippines, Palladin Institute of Biochemistry, Ukraine, Taiz University, Yemen, Universität Hamburg, Germany, University of Milan, Italy, University of Turin, Italy, Delft University of Technology, the Netherlands, University of Coimbra, Portugal, and University of Uppsala, Sweden. See http://landaunetwork.org/index.php/eu-cbrn-coe-project-18-project-factsheet for more information

[19] The questionnaire survey for professors was designed based on the model described below, and in 2013 surveyed 376 HEIs faculty members from ten countries (Georgia, Jordan, Lebanon, Morocco, Moldova, Pakistan, Philippines, Ukraine and Yemen.). Nine educational seminars reached 527 students in nine universities and institutes in seven countries (Quaid-i-Azam University, Pakistan (25 March 2014, 74 students/68 post-instruction questionnaire respondents), Hashemite University, Jordan (27 March 2014, 22 students/22 post-instruction questionnaire respondents), University Mohammed V-Agdal, Morocco (17 April 2014, 37 students/24 post-instruction questionnaire respondents), Palladin Institute of Biochemistry, Ukraine (25 April 2014, 79 students/73 post-instruction questionnaire respondents), Saint Joseph University, Lebanon (30 April 2014, 20 students/20 post-instruction questionnaire respondents), National Center for Public Health, Moldova (5-6 May 2014, 100 students/80 post-instruction questionnaire respondents), Abdul Wali Khan University, Pakistan (23-24 May 2014, 148 students/142 post-instruction questionnaire respondents), Al Akhawayn University, Morocco (24-25 June 2014, 29 students/no post-instruction questionnaire respondents), National Center for Disease Control and Public Health, Georgia (8 September 2014, 24 students/24 post-instruction questionnaire respondents). An additional seminar was organized for faculty members rather than for students by University of the Philippines College of Medicine, Philippines (6 November 2014)) and included a post-instruction questionnaire for students developed on the models used for the “Fostering the Biosecurity Norm”, “Pakistan”, and “EUBARNet” projects, completed by 453 students from eight seminars. Among students who responded to the questionnaires, 11% were undergraduate students, 65% Master students, and 23% during their PhD or post-doc. Both the questionnaire survey on professors and the post-

and co-facilitated the final workshop of the project.[20] In the thesis this project is referred to as "Project 18".

Data on four additional countries is leveraged from six projects in which I was involved in, as Project Lead at Sandia National Laboratories' International Biological and Chemical Threat Reduction (IBCTR) (Sandia National Laboratories, 2014a) during 2013-2015. Management of data from these projects required additional measures, including complying not only with the University of Bradford Humanities, Social and Health Sciences Research Ethics Panel's requirements but also with those of Sandia's Human Subject Research Board; and that countries of operation or partner organizations cannot be disclosed. Notwithstanding the required anonymization of countries and institutes, the Table below provides a characterization of these countries basing on some social, economic and scientific indicators[21] to suggest how these countries provided experiences on education to mitigate deliberate disease risks within additional social, economic, academic and scientific contexts.[22]

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instruction survey for students were administered and collected locally by partner HEIs, and results were organized, tabulated and analysed by project officer at LNCV.

[20] Held in Como, Italy, in 26-27 November 2014. See http://landaunetwork.org/index.php/2014/11/eu-cbrn-coe-project-18-international-network-workshop-como-italy/ for more information

[21] This arrangement for data management has been discussed with Sandia National Laboratories managers and at the PhD Progression Review Meeting on 17 June 2014, described in the Progression Review Memo of 15 July 2014, and approved by the University's Progression Review Panel on 28 July 2014.

[22] Implementation of these projects leveraged pre-existing instructional materials designed and developed by IBCTR on the education plan of research, notably the Global Biorisk Management Curriculum (GBRMC) (Sandia National Laboratories, 2013); and included the development of specific train-the-trainer materials on instructional design for the instruction design plan of research, based on Sandia's pre-existing Trainer Development Program (TDP). Sandia's original TDP is designed and developed to build training capacity in a professional and in-service context, while the new materials were adapted to build instructional, including curriculum design, capacities in a higher education and pre-service context. The new train-the-trainer materials were indicated as Trainer and Curriculum Development Program (TCDP).

Table 1 - Undisclosed countries characterization

Country	Language[23]	Religion	Nominal GDP per capita/year	SJR intl Science Ranking[24]
A	Official 1	Religion 1 > 80%	< 1,000 $	1-100
B	Official 2	Religion 2 > 90%	1,000 – 5,000 $	100-150
C	Official 1	Religion 3 > 70%	1,000 – 5,000 $	1-100
D	Official 2	Religion 2 > 90%	> 5,000 $	1-100

The project in Region A included activities in six countries of the region of, and including, Country A. The project was implemented in 2013-2014 and included an online investigation on curricula contents and a train-the-trainer workshop on instructional systems design (ISD) for educators in higher education.[25] In the thesis this project is referred to as "Region A".

University 1 of Country A is an animal health HEI in Country A. University 1 was also included in the Region A project. University 1 was engaged in discussions on education on biorisk management and, due to the interest of its leadership and the assistance in design by Sandia experts, BRM was formally included in a course within the degree of Master of Veterinary Medicine.[26] In 2013, the author together with colleagues facilitated an educational seminar for thirteen students including introductory courses on

[23] Language, religion and nominal GDP per capita per year from Wikipedia.

[24] "The SCImago Journal & Country Rank (SJR) is a publicly available portal that includes the journals and country scientific indicators developed from the information contained in the Scopus® database (Elsevier B.V.). These indicators can be used to assess and analyze scientific domains. […] SCImago is a research group from the Consejo Superior de Investigaciones Científicas (CSIC), University of Granada, Extremadura, Carlos III (Madrid) and Alcalá de Henares, dedicated to information analysis, representation and retrieval by means of visualisation techniques" (SCImago, 2016). See http://www.scimagojr.com/countryrank.php for more information.

[25] I carried out the online investigation in 2013, which was based on the model described below, and surveyed 138 degree courses in 14 HEIs. The ISD workshop lasted five days in 2014; participants included fourteen educators from the same number of either public health or animal health HEIs in the region, along with trainers-to-be from governmental bioscience institutes, Ministries of Health and Ministries of Animal Resources of the six countries, for a total of 24 participants. The same participants were surveyed with the email questionnaire survey (21 respondents out of 24 participants).

[26] Largely because the engagement on biosafety and biosecurity education happened at the same time when the curriculum for the Master's, planned to start with the first edition in 2013-2014, was being drafted.

biosafety and biosecurity from the GBRMC.[27] In the thesis this project is referred to as “Country A University 1”.

University 2 from Country A is a HEI offering degrees on science, technology and medicine. The author and colleagues worked with this university in 2014 and 2015 to introduce education on biosafety and biosecurity in the medical degree courses. University 2 was also included in the online investigation within the Region A project. The project included a questionnaire survey on faculty members from the Faculty of Medicine and an ISD workshop in 2014 with 29 participating faculty members and educators. In the thesis this project is referred to as “Country A University 2”.

The project in Country B has been pursued between 2013 and 2015. It included a questionnaire survey in two phases on HEIs educators and two ISD workshops.[28] In the thesis this project is referred to as “Country B”. The project in Country C spans 2014 and 2015. Among other tasks less relevant for this research, it included an online investigation on curricula contents; an educational seminar for students on biosafety and biosecurity; a questionnaire survey for professors; and an ISD workshop for professors.[29] In the thesis this project is referred to as “Country C”. The

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[27] The seminar constituted the biorisk management section of the course also covering diagnostic techniques in the Master syllabus. The seminar included evaluation questionnaires that are considered in the education plan of the research.

[28] The questionnaire surveys were designed in line with the model described below and involved ten participants from six Country B HEIs in the first year and seventeen in the second year. The same professors participated to the surveys and the ISD workshops, and were identified and invited from previous training courses on biosafety and biosecurity and by recommendations of previously engaged professors in Country B. The survey was administered via email in 2014 had 17 respondents; the first ISD workshop was organized in 2014 and had ten participants from nine universities/schools in Country B and faculties of science, medicine, pharmacy, and veterinary; participants mainly included lecturers and professors but also two deans. The second ISD workshop was organized in 2015 with 16 participants, including twelve returning participants and four participants from HEIs not previously represented. The 2014 ISD workshop focused on the Analysis and Design phases of the ISD ADDIE model on the instruction design plan of research, while the 2015 ISD workshop focused on the Development, Implementation and Evaluation phases of the ISD ADDIE model on the instruction design plan of research. See below for the explanation of ISD workshops and the next Chapter on the theoretical background.

[29] I carried out the online investigation in 2014 based on the model described below and surveyed 50 degree courses from fifteen HEIs in Country C; I facilitated with one colleague the seven-days

project with Country D was implemented in 2014, and the activities considered for this research include a questionnaire survey and an ISD workshop.[30] In the thesis this project is referred to as "Country D".

1.8 Data collection and analysis methods

The research combines different methods of primary and secondary data collection, generation and analysis in terms of mixing qualitative and quantitative data but also in a "multi-strategy" (Robson, 2011 p. 161) to not only best exploit different tools but also to reflect the variety of contexts offered by pre-existing data, reflect that supported by literature on science in society (Letherby et al., 2012), reflect my situation and mental model as researcher,[31] and improve validity. As Mason (2006) explains, there are different underpinning logics in the decision to mix methods of research.[32] In the case of this research, the decision on mixing quantitative and qualitative methods relies on both Mason's "corroborative" and "integrative" logics. Data collection from a variety of sources and methods also strengthens the research with "triangulation" (Bryman, 1998).[33] Finally a

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educational seminar for students to thirteen PhD students from one HEI in 2014 using GBRMC materials; carried out the questionnaire survey for professors; and facilitated with one colleague the five-days ISD workshop with nine participants from five HEIs in 2015.

[30] The same professors participated to the survey and the workshop, and were identified from a range of universities, and representing a variety of Country D's provinces, scientific sectors (medicine, biology, biotechnology, veterinary), and roles (lecturers, heads of departments, deans), thanks to the advice of previously engaged institutional partners in Country D. The survey was administered via email in 2014, and I facilitated the five-days ISD workshop in 2014 to 20 participants from ten HEIs of Country D. This workshop included introductory materials on biosafety and biosecurity from GBRMC and for the ISD section only covered the Analysis and Design phases of the ISD ADDIE model on the instruction design plan of research.

[31] I would describe a mental model as a way to think, view or shape the world, which summarizes personal ontological and epistemological convictions, and is at the same time the result of, and the influence on, personal history, experience, education and beliefs. Mental models are described by Greene (2007 p. 12) as the sets of "assumptions, understandings, predispositions, and values and beliefs with which all social inquirers approach their work".

[32] Including a "rhetorical" logic to illustrate with a broader picture in-depth analysis; a "parallel" logic to answer separate questions; an "integrative" logic to address strongly linked questions; a "corroborative" logic that uses triangulation to reinforce results; a "multi-dimensional" logic standing in between of the "parallel" and the "integrative" ones; and finally designs mixing methods for opportunistic reasons.

[33] See also Hakim (2000 p. 173) for a discussion on the "triangulation" term. The integrative logic of mixing quantitative and qualitative methods is also key as the research aims to assess and investigate different parts of the problem of "promoting education on a specific subject" that can

multi-strategy design is attractive for research with multi- and inter-disciplinary aspects, as suggested by Bryman (2006). The research combines data collection and analysis methods including content analysis; questionnaire surveys; educational interventions for students on the education plan of research and train-the-trainer workshops for professors on the instruction design plan of research (both including evaluation questionnaires); and semi-structured interviews. Following Johnson (2001), such a design can be considered as an exploratory non-experimental[34] part of a multi-strategy exploratory and explanatory research project (Creswell, 2003). Indeed the research did not aim to gain statistically significant or representative results to be generalized to any larger population than the groups and samples they are collected from, such as the countries of collection, any other context, as well as "scientific HEIs", "students", "science educators", or even "scientists". The samples of HEIs in online investigations are not randomized, but opportunistic, and often selected on the criterion of the "best HEIs" in the country or region, as discussed later. Participants in questionnaire surveys have also been sampled opportunistically based on contacts identified by the online investigation; existing relationships; or participation in other phases depending on the project. While not claiming generalizability, however, discussing this data the research provides firstly a valuable illustrative picture of information, examples, and trends from groups and samples in a large number of contexts; and secondly the opportunity to develop and operationalize the proposed design and evaluation tools for education as a potential risk mitigation measure.

The data collection and analysis tools are interlinked. Content analysis for securitization processes allowed identifying possible features of education as a security tool as envisaged by its proponents, while content analysis of

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each be best assessed with different methods: some data, such as number of educational opportunities and their place in the academic context, for example, are numerical, while others, such as the value of those opportunities for the students or the professors, or indeed the feelings, the attitudes and the priority settings of the actors involved are best investigated and explained with qualitative data.

[34] Because of the two combined limitations of non-randomization of samples, as discussed below and impossibility of controlling the independent variable, i.e. the "inputs" others from those researched.

the educational offerings of the HEIs provided the opportunities to study them but also to collect contacts to include in subsequent surveys. Surveys enlarged and explained the information and collected quantitative and qualitative data on levels of awareness, opinions and attitudes. Educational interventions and ISD workshops were organized with the data from content analyses and surveys in mind and included post-instruction questionnaire surveys and/or tests. Finally, interviews involved professors who had participated in one or more of the projects outlined above and could provide data for both the education and the instruction design plans of research.

1.8.1 Content analysis

This research method was applied to securitization analyses and to the Analysis phase of the ISD ADDIE model. The former has been used mainly to discuss the first research question and identify securitization agent(s); securitization argument(s); context; targeted audience; and emergency measures urged by the attempted securitization moves. Theoretical background of securitization analysis is discussed in further detail in the next Chapter, and results are presented in Chapter 4. Regarding the latter, publicly available documents from HEIs were consulted regarding contents of educational offerings, including online or paper programmes, syllabi of degree courses, learning objectives, descriptions and guidelines. Content analysis[35] is recognized as useful for

[35] Content analysis is "the quantitative analysis of what is in the document" and an unobstrusive measure "which is non-reactive, in that the document is not affected by the fact that you are using it" (Robson, 2011 p. 349). Content analysis is a data collection and analysis technique to systematically characterize a text or other meaningful material (Neuman 1997) and that can include quantitative and qualitative features. In social research, the technique has been applied *inter alia* to the analysis of political discourses, media, academic publications and legislation. As minimal common characteristics, content analysis would require a coding scheme based on decided categories, the analysed text, and a coder, either human or automated. Sampling of the body of knowledge analysed is acceptable, common and often desirable – in a sense content analysis shares features of survey research, though looking at "non-human" samples for gathering information. Though content analysis is a developed and widely applied approach, here it is used in a basic version that complies with a general definition such as "an interactive process between a careful reading of the text, design of preliminary coding categories, fitting of texts into these categories, and refinement of categories till most test can be fitted into the existing set of categories *given the specific research needs of the investigator*" (Franzosi 2008 p. xxv, emphasis in the original).

studies involving educational establishments (Robson, 2011, p. 351) and had already been used in studies on biosecurity in universities (Mancini and Revill, 2008; Mancini and Revill, 2009; Revill and Mancini, 2010; Minehata, 2010; Minehata and Shinomiya, 2009; Minehata and Friedman, 2009). Content analysis, especially that based on online-available documents of HEIs and here indicated with "online investigations" (Franzosi, 2008) was carried out by running searches of relevant keywords and noting the number of occurrences and the relationships with key features of the context in which they were embedded. Pages of university websites were scanned looking for mention of learning objectives; syllabi; or bibliography of degree courses, courses, curricula and modules to look for existing references. Keyword selection based on the experience of previous research and included terms such as: "security", "safety", "dual-use", "misuse", "risk", "prevention", "weapon", ethics", "responsbility", "hazard", "threat", "conduct", "hygiene", "PPE", including their local translations if applicable, and making judgment calls if references were actually relevant for deliberate disease and connected risks management.[36] This led to the information discussed in Chapter 5 and opportunities to leverage for what was discussed under Chapters 6 and 7; as well as to identify individuals to engage with other methods described below. Advantages of online investigations include that they could offer a preliminary overview not depending on availability or bias of individuals and local partners.[37] A limitation though is that it fundamentally relies on information available online: in some cases that information may be scarce, non-existent, unclear or outdated.[38] Another disadvantage is that such an investigation may take a long time, searching large numbers of webpages. Another strategy is to look at samples of universities. This has been done

[36] Information was then coded and categorized under the biosafety, biosecurity, bioethics, biorisk management and/or dual-use categories. See Berelson (1952) for guidance on categorization in content analysis and Schiffrin (2001) for discussion on markers and language.

[37] Content analysis on curricula content gives an important contribution to internal validity and reliability: it bases on data from the "official source" of the HEIs, and does not risk to be biased by opinion (or ignorance) of people.

[38] For example, contacts with Moroccan and Pakistani universities demonstrated that online investigations I had previously carried out had portrayed a very incomplete image of the existing educational offering. Hence online investigations have not been pursued in those projects and those incomplete results have not been retained.

in the EUBARNet, Region A and Country C projects selecting the "best"[39] HEIs to survey.[40] Online investigations on educational offerings in HEIs was used in the EUBARNet (184 surveyed degree courses), Region A (138 degree courses surveyed), and Country C (50 degree courses surveyed) projects. A model of data tabulation is reported in the Appendices.

1.8.2 Questionnaire surveys

Questionnaire surveys have been used to gather data on existing educational offerings, considerations in higher education programmes relevant for education on deliberate disease risks, opinions and attitudes of educators and/or students, levels of awareness and competences on biosafety and biosecurity, and processes to introduce education to mitigate deliberate disease risks. Data from questionnaire surveys is used to discuss the second and third research questions, is leveraged on both the education and instruction design plans of research, and is mainly presented in Chapter 5 on Analysis and Chapter 6 on Design.

A questionnaire survey on students was used in the Pakistan project (448 respondents), while questionnaire surveys on professors were used in the Morocco (227 respondents), EUBARNet (20 respondents), Project 18 (376 respondents), Region A (21 respondents), Country A University 2 (27 respondents), Country B (17 respondents), Country C (9 respondents), and Country D projects (9 respondents).[41]

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[39] According to HEIs rankings such as The Times Higher Education World Ranking of Universities (THE, 2016) or the Webometrics national rankings (CSIC, 2016).

[40] This sampling strategy is firstly practical and due to the better chance of obtaining information from those universities, that often describe with larger detail their educational programs; secondly, the issue of generalizability is addressed with a modelling (or "championing") driven approach, assuming that an educational policy change in the best universities would eventually push the other institutes to follow those "models", as it happens in other educational offerings. Generalization is turned to the future and to the possible/probable educational policy trends, rather than on the current status of the populations from which the samples are taken; apart from this, the results of the research should be seen as an illustrative picture of just those leading institutes included in the project.

[41] The questionnaires used in the Pakistan and Morocco projects were designed based on the experience from the 2008-2009 "Fostering the Biosecurity Norm" project (Mancini and Revill, 2008; Mancini and Revill, 2009; Revill and Mancini, 2010), designed with in-country partners and piloted before final administration. I designed the questionnaire for the EUBARNet project already with the

1.8.2.1 *Administration*

Questionnaires were administered via the Internet, email, in paper or compiled through telephone or in-person interviews.[42] The EUBARNet questionnaire survey[43] was administered through the Internet with a private link included in an email invitation.[44] One of the risks of a web-based survey is a coverage error due to accessibility to the Internet. However, literature shows that university communities may be a case in which response rates to Internet surveys are higher than with others methods (Fricker, Jr., 2008). Another risk is response bias, in particular that only contacted participants who have an interest in the subject complete the survey (Coomber, 1997). This was a concern as previous experience show how many in academic communities may see deliberate disease risks as an irrelevant subject (Dando and Rappert, 2005).[45] Another risk was to get a low response rate; previous similar surveys (Mancini and Revill, 2008; National Research Council and American Association for the Advancement of Science, 2009) got response rates lower than 20%. Roster et al. (2004) say that web based surveys generally get lower response rates than those using other methods.[46] Mitigation measures for these methodological risks included: the stress on the

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present research in mind and submitted it as an assignment for the PGR School in 2012. Subsequent questionnaires for professors used in the Project 18, Region A, Country A University 2, Country B, Country C and Country D projects were somehow based on, and developed, that same model. Project 18 also included a questionnaire survey directed to students, but was implemented as part of the educational interventions methods and is mentioned below. In Pakistan, partners carried out a new questionnaire survey using the same data collection tool in 2014-2015 (Tanveer and Shinwari, 2015b).

[42] In some cases, multiple administration methods were used in the same survey to increase response rates.

[43] The survey was realized with the WPQuiz plugin for Wordpress, the Content Management System used for the EUBARNet website, which allowed the use of sections, HTML and hyperlinks.

[44] As Coomber (1997) explains, there is little point in setting up a page and waiting people to come! The email was personalized, translated in the language of the invited participant, and quoting their courses as emerged from the online investigation. It pointed to an attached cover letter for more information and provided the link for the survey. The link landed on a password-protected page, set to prevent *bots* from search engines to index it, but with the password embedded in the link so that the participant did not have to actually type it.

[45] To face this, the presentation in the letter stated that reports to the European Commission would include positive *and* negative feedback.

[46] Reasons for a low response rate may vary and include: scarce interest in the subject; message identified as spam or undesired; unwillingness to provide profile questions.

objectives of the research; copying in the message colleagues of the participant, who already participated to the project; stressing that I already had the public information on curricula contents; and other good practices (Dillman et al., 2009). A further risk was that somebody outside the population of faculty members would compile the survey. Both technical checks and triangulation with the other data collection methods mitigate this risk.[47]

The questionnaire survey on students in the Pakistan project was administered in paper with the collaboration of professors and researchers from several HEIs, who distributed the questionnaires to their classes.[48] Returned questionnaires were mailed, or scanned and emailed, to QAU and collected by local colleagues and me. The questionnaire survey on professors in the Morocco project was administered via email and/or compiled during in-person interviews with the collaboration of members of AMBS in each Moroccan HEIs having courses of biology, biotechnology, medicine or pharmacy.[49] Returned questionnaires were emailed to AMBS and collected by local colleagues and me. The questionnaire survey on professors in Project 18 was administered via email and/or compiled during face-to-face interviews by partner organizations in each country reached by the project.[50] Returned questionnaires were emailed to LNCV and collected by LNCV researchers. The questionnaire survey on

[47] The completion of the survey was limited to one per computer; the survey was not reachable without the link provided in the invitation, nor was indexed by search engines; thirdly, the information gathered could be cross-checked with that from the online investigation. Finally, a quote on the interest of the European Commission may have led professors to think, “my course does not include something it should” and to socially desirable answers. I also tried to mitigate this risk, reiterating the condition of anonymity, and being clear in the introduction that there was not a strong “desirable position”.

[48] The target community being students (undergraduate, graduate or postgraduate) of life sciences and technologies.

[49] The criteria to identify an interviewee were to be a professor, other faculty member or a practicing scientist who are involved with the education of students; and to teach in degrees (“filieres”) of Licence or Master of life sciences or biotechnology. This led to a population of mainly life scientists, but also medical doctors, chemists, veterinaries and other scientists, sharing the fact of teaching to life sciences and technologies students.

[50] Inclusion criteria were to be professors or other faculty members from the same or other HEIs in the country teaching in life sciences and technologies, public health, medicine or pharmacy degree courses.

professors in the Country A University 2 project was administered by colleagues at the local HEI and collected by them and then me. The questionnaire surveys on professors in the Region A, Country B, Country C and Country D projects were administered via email to invited participants to ISD train-the-trainer workshops a few weeks prior to the event. Compiled questionnaires were returned to me and other colleagues.

1.8.2.2 Samples

Samples surveyed with questionnaires were non-probabilistic and the result of opportunistic or snowballing sampling. For the EUBARNet survey, contacted professors were identified from the online investigation on curricula contents; for the Morocco, Pakistan and Project 18 surveys, they were identified by local partners based on pre-existing contacts and trying to reach a large number of respondents in a range of HEIs, sectors and degrees. For Region A, Country A University 2, Country B, Country C, and Country D surveys, participants were professors invited to ISD train-the-trainer workshops who had been identified from previous trainings on biosafety and biosecurity or by suggestions from local partners trying to reach a range of HEIs, sectors and degrees in each country. Twenty respondents, for a very low response rate of around 10%, completed the EUBARNet questionnaire. In the Pakistan project, 507 questionnaires were returned and 448 validated;[51] not all participants answered all questions.[52] In the Morocco project, 227 individuals completed the questionnaire, even if not necessarily answering all the questions.[53] The questionnaire survey in Project 18 was completed by 376 professors or faculty members. Twenty-one out of 24 invited participants completed and returned the questionnaire Region A survey; 27 out of 29 participants for the Country A University 2 survey; seventeen out of twenty participants for the Country B survey; nine out of nine for the Country C survey; and nine out of 20 for the Country D survey.

[51] The rest being double submissions.

[52] The students in this sample were from 24 HEIs in Pakistan, roughly one-fifth of the institutions previously identified as offering higher education in the life sciences and technologies.

[53] From thirteen HEIs in the country, all those offering higher education in the life sciences and technologies.

1.8.2.3 *Structure*

The questionnaires had a common structure, with variations due to local needs identified by interaction with partner organizations or feedback from pilots and improvements in subsequent versions. Questionnaires were drafted with good practices to improve internal validity in mind such as clear and not leading questions, ensuring respondents have the knowledge needed to understand them, and asking each only one thing (Robson, 2011; De Vaus, 2001; Saris and Gallhofer, 2007). Questionnaires started with an introduction or a cover letter outlining objectives and framework of the research, links to the project responsible persons or organizations, information on personal data management, and in some cases on the number of questions and the time estimated for completion. Questions were then organized in a profile section and sections on levels of awareness and competences; educational opportunities; and opinions and attitudes. Profile questions typically included country;[54] scientific area of the institution or faculty of affiliation; the specialization area of the respondent and the level at which they taught[55] and in some cases the approximate number of students taught per year. Questions on current awareness and competences were included in different forms in the Pakistan, Morocco, Project 18, Region A, Country B, Country C and Country D surveys. The Pakistan questionnaire asked students if they had ever heard of key terms and to provide a brief definition showing their own understanding of some terms.[56] Other questions assessed knowledge levels on organizations and initiatives regarding dual-use research, legislation, and codes of conduct, and/or if the respondent had ever received training on biosafety, biosecurity or biorisk management. The third section generally aimed at getting information about existing educational opportunities and references relevant for deliberate disease risks given in higher education

[54] For multi-country projects like EUBARNet, Project 18 and Region A.

[55] Or, for students, in which they studied. Scientific fields were categorized according to what emerged by online investigations or feedback from pilots. Respondents were allowed to select multiple options and/or to indicate additional ones under “other”.

[56] Including bioethics, biosafety, biosecurity, bioweapons, bioterrorism, dual-use research, the Biological and Toxin Weapons Convention, and Codes of Conduct.

programmes.[57] The concept of "considerations currently given" was operationalized in the information that the respondents were able to give about the contents of courses, either directly because they taught those contents, on indirectly because they coordinated, or were aware of, work of others. The dimensions selected to describe existing considerations were: their existence; their extent, quality and nature in case of inclusion; and reasons for not inclusion. Answers were given with a combination of options, with variables in the closed questions decided according to replies to previous similar studies and feedback from pilots. Generally a fourth section of the questionnaire aimed at eliciting the opinions and attitudes of respondents on deliberate disease risks and the role of education (including its perceived relevance, importance and urgency), in some cases including questions on risk perceptions, learning objectives, and/or on the systems to introduce or change educational programmes and related challenges and opportunities. Questions formats included multiple-choice closed questions[58], Likert scales[59] to assess opinions on different items, and/or open questions. Questionnaires were circulated in English for the Pakistan, EUBARNet,[60] Project 18, Region A, Country A University 2 and Country C projects. The questionnaire for the Morocco project was

[57] Definitions of key terms such as biosafety, biosecurity or biorisk management from sources including the WHO Biosafety Manual and Biosecurity Guidance (WHO, 2004; WHO, 2006) or the CWA15793 (CEN, 2011) were indicated before this section or in a glossary.

[58] The questionnaire for the Pakistan survey was distributed in two waves in 2011 with slightly different versions, with some questions being presented in binary closed questions (yes/no) in the first version and in Likert scale in the second version. In these cases, the answers to the second version were recoded as binary accordingly. 177 respondents answered the first version and 271 the second version.

[59] Guidance on how to develop Likert scale questions, items, and ranking systems has been followed from Robson (2011).

[60] Given its multi-country scope, it was discussed with pilots participants if using English would have been a disadvantage, or if translating to the local languages was a better strategy. Accepting a generally agreement that in the European scientific academic community, English is universally used, it has been suggested by pilot participants how using English in the questionnaire would have helped the internationalization of the project. Furthermore, using only one language made much easier the administration of questionnaire. In the view of personalization and to facilitate engagement, however, we decided to translate in the respondent's language (Italian, Portuguese, Spanish, etc) the email message accompanying the invitation.

circulated in French.[61] Questionnaires for the Country B and Country D projects were circulated in a bilingual version, and respondents had the option to answer in English or in their language. Questionnaires explained how data would be managed, by whom and under what conditions. As a general rule, anonymity was granted to respondents, while confidentiality was granted with regard to personal information, which could be used only for the purposes of the project (for example for follow-up activities), in case they expressed interest to be further involved.[62] Sample models of questionnaires are reported in the Appendices.

1.8.2.4 Data analysis

Answers to closed multiple-choice or Likert scale questions were codified and tabulated into software applications to generate quantitative data. Microsoft Excel was used to organize and analyse data from all surveys.[63] Excel and/or the other applications were used to generate frequency distribution tables, cross-tables, descriptive statistics and/or graphs.[64] Answers to open questions, such as from the section on levels of awareness and competences and the section on opinions and attitudes, were anonymized, collected and coded into categories (such as for

[61] Questions and answers in French are translated (by the author) into English in the thesis. Original text is provided in the footnotes.

[62] Respondents were explained that personal information under the profile section was, anyway, optional. The questionnaire model for the EUBARNet survey explained that data (besides personal information) could be used for the project and other academic research.

[63] The SPSS and R packages were also used for the Morocco and Pakistan surveys. The WPQuiz plugin for Wordpress used for the EUBARNet survey also provided automatic tabulation, however it only recorded answers of individual respondents, so results were then compiled into Microsoft Excel.

[64] Statistical analyses including statistical significance tests of individual shares of answers to multiple-choice questions; and statistical independence analysis of data from cross-tables with chi-squared goodness of fit tests and Fisher exact tests were carried out on results of the two largest questionnaire surveys, that on professors in Morocco and that on students in Pakistan. While tests results were generally positive, given the above considerations on the intended representativeness and significance of the research results, and that statistical analysis has not been carried out in the other projects for the same reasons, tests results are not reported in the thesis.

prioritized learning objectives suggested by professors) or flagged for particularly relevant quotes.[65]

1.8.3 Educational interventions

Educational interventions on deliberate disease risks, targeting students of higher education degrees in life sciences and technologies, public health, medicine or animal health fields, have been carried out as part of the education plan of the research. These experiences, and data from relative evaluation questionnaires, are used to discuss the second and third research questions, and are mainly presented in Chapters 7 and Chapter 8.

Educational interventions took the form of one or multi-day seminars or workshops, and in-person or distance courses. They included lecturing and active learning techniques to different extents. Contents spanned a range of topics within the biosafety, biosecurity, biorisk management and bioethics subject matters. Instructional materials were developed specifically for the research (such as for the Pakistan and ISIS projects and some seminars of the EUBARNet and Project 18 projects) or leveraged pre-existing resources, such as the EMR (for some seminars of the EUBARNet project) and the GBRMC (for the Country A University 1 and Country C projects). Participating students were selected in concert with their local professors, and/or basing on their enrolment in degrees where the course was inserted. Educational interventions were realized in the Pakistan (1 intervention, 12 students from one HEI and one country, one-day seminar); EUBARNet (7 interventions, 268 students from 7 HEIs and 6 countries, one-day seminars); Project 18 (9 interventions, 527 students from 9 HEIs and 7 countries, one or two-day seminars); ISIS (1 intervention, 25 students from one HEI and one country, distance learning course); Country A University 1 (1 intervention, 12 students from one HEI in one country, five-day seminar); and Country C (1 intervention, 15 students from two HEIs in one country, five-day seminar) projects.[66]

[65] Quotes are reported with a coding system for respondents, with letters indicating the project and the HEI of the respondent and numbers indicating the individual respondent. Codes are indicated at the end of quotes in square brackets.

[66] More detailed information on educational interventions is provided in Chapters 7 and 8.

Educational interventions included post-intervention evaluation questionnaires to gather feedback from students as well as to test learning objectives. Two main models were used, the former developed basing on the experience of the 2008-2009 "Fostering the Biosecurity Norm" project, itself based on widely tested reaction questionnaires that students compiled on regular courses in their HEIs and which were offered as examples by engaged professors. That model was further developed and integrated with knowledge questions relevant to deliberate disease risks, and versions were used in the Pakistan, EUBARNet and Project 18 projects.[67] Post-instruction questionnaires used in the interventions in the Country A University 1 and Country C projects were based on standardized surveys developed by Sandia National Laboratories and made available to trainers as part of the GBRMC. The ISIS and the Country A University 1 projects also included specific post-instruction evaluation and assessment methods to evaluate learning.[68]

Post-instruction evaluation questionnaires were anonymous and students were told that no personal information would be used for scopes outside that of the projects, and that aggregated data could be used for the specific projects and academic work. Data from questionnaires was anonymized were necessary, coded and compiled into Microsoft Excel for analysis to generate quantitative data. Answers to open questions were anonymized, collected and coded into categories or flagged for particularly relevant quotes.[69] Sample models of post-instruction questionnaires are reported in the Appendices.

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[67] The EUBARNet and Project 18 questionnaires for students were designed and administered with two parts, one to be compiled before the educational intervention and one post the educational intervention. Questions for the pre-seminar section have been developed on the model of the Pakistan survey for students and other questionnaires for professors and are included in the discussion in Chapter 5.

[68] Response rates to post-intervention surveys included all participating students except for the interventions in the EUBARNet (210 in six seminars out of 268 students in seven seminars; questionnaires could not be used in the seminar in Sweden) and Project 18 (453 in eight seminars out of 527 students in nine seminars; questionnaires could not be used in the second seminar in Morocco) projects.

[69] Quotes are reported with a coding system for respondents, with letters indicating the project and the HEI of the respondent and numbers indicating the individual respondent. Codes are indicated at the end of quotes in square brackets.

1.8.4 ISD train-the-trainer workshops

Workshops on instructional design for professors and educators to create education as a tool to limit deliberate disease risks have been carried out as part of the instruction design plan of research. They have been used mainly to discuss the third research question, and their results are presented in Chapter 7 and Chapter 9. Workshops were organized along the phases of the ADDIE ISD model[70] and typically had a format of a five-day in-person workshop.[71] ISD workshops were realized in the Region A (24 participants), Country A University 2 (29 participants); Country B (10 participants to the first workshop, and 16 to the second workshop); Country C (9 participants); and Country D (20 participants). Post-workshops questionnaires for participants were also used, based on the standardized surveys model developed by Sandia National Laboratories. Post-workshops questionnaires were anonymous and participants were told that no personal information would be used for anything outside that of the projects. Data from questionnaires was anonymized where necessary, coded and compiled into Microsoft Excel for analysis to generate quantitative data. Answers to open questions were anonymized, collected and coded into categories or flagged for particularly relevant quotes.[72] ISD workshops included templates for exercises on instructional design that generated qualitative data.[73] Sample models of post-workshop questionnaire are reported in the Appendices.

1.8.5 Semi-structured interviews

Semi-structured interviews of professors who had been actively engaged in promoting and implementing education as a potential tool to mitigate deliberate disease risks is a tool specifically designed for this research,

[70] See the next Chapter for further details.

[71] However, in the Country B project it was split into two workshops, a first one covering Analysis and Design and a second one covering Development, Implementation and Evaluation; and in the Country A University 2, Country C and Country D projects it only covered the Analysis and Design phases. Subsequently to the workshops, the author and colleagues mentored participants on refining their designs; and to practice implementation.

[72] Quotes are reported with a coding system for respondents, with letters indicating the project and numbers indicating the individual respondent. Codes are indicated at the end of quotes in square brackets.

[73] Quotes are coded with a code for the type of document (such as "DD" for design documents), letters for the project, and numbers for the individual respondent.

collecting data that is exclusive to the thesis. Data from interviews are used to discuss the second and third research questions, and their results constitute a major contribution to Chapter 8 and Chapter 9. Eligibility criteria for interviewees included having been involved for at least one full academic year in one or more projects that I had coordinated or was involved in, and who had implemented education to their students. The interviews were semi-structured in that I prepared a schedule and checklist of points that included a recollection from the respondent on how they became involved in education on deliberate disease risks; and then touching the four levels of evaluation on the educational and instruction design plans of research.[74] The interview schedule, and an information and consent sheet for interviewees, were reviewed and approved by the Chair of the Humanities, Social and Health Sciences Research Ethics Panel at the University of Bradford. I interviewed nine professors, all involved in one or more of the projects presented above. I contacted professors via email explaining the interview proposal and to arrange an appointment; all invited professors accepted the interview. Five interviews were carried out in 2014; three in 2015; and one in 2016. The shortest interview lasted 23 minutes, the longest one hour and seven minutes. Six interviews were carried out in English, two in French and one in Italian.[75] At the beginning of the interview, I presented the Information and Consent Sheet to be signed, retained the signed copy[76] and asked permission to

[74] See the next Chapter for further theoretical details, and Chapters 8 and 9 for results. A semi-structured interview denotes when "the interviewer has an interview *guide* that serves as a checklist of topics to be covered and a default wording and order for the questions, but the wording and order are often substantially modified based on the flow of the interview, and additional unplanned questions are asked to follow up on what the interviewee says" (Robson, 2011 p. 280). The semi-structured design "is most appropriate when the interviewer is closely involved with the research process (e.g. in small-scale project when the researcher is also the interviewer)" (Robson, 2011 p. 285) like in this case. In designing and carrying the interviews I considered suggested good practices such as the use of probes, prompts, schedule, introduction, taping, and analysing (Robson, 2011; Weiss, 1995).

[75] In the thesis, I translated into English the quotes from the French and Italian interviews, keeping originals in footnotes. The translation was focused on the "functional equivalence" rather than "literal identity", as suggested by Hakim (2000).

[76] I also anticipated the document via email.

record the conversation. I then transcribed[77] the recordings and anonymised[78] all references to the interviewee, other individuals, organizations, HEIs and countries.[79] Transcripts were analysed using thematic coding and identification of themes.[80] The semi-structured interview schedule and the Information and Consent Sheet are reported in the Appendices.

Table 2 - Use of different data gathering tools in the projects considered by the research

	Morocco	Pakistan	EUBARNet	ISIS	Project 18	Region A	Country A University 1	Country A University 2	Country B	Country C	Country D
Online investigation			X			X				X	
Questionnaire survey	X	X	X		X	X			X	X	X
Educational interventions		X	X	X	X		X			X	
ISD workshops						X		X	X	X	X
Interviews	X	X	X	X	X		X		X	X	

1.9 Ethical Issues

This research involved a number of ethical issues. Firstly, there are considerations related to data collection and generation, in particular for those methods involving people such as questionnaires and interviews.

[77] In the transcriptions, underlined text denotes emphasis; a comma (",") and points ("…") denote a short and a long pause in talking, respectively; the "…" at the end and beginning of lines indicate an interjection as the person continued talking.

[78] Quotes from interviews are reported in the thesis with a coding system for respondents, indicated from "Professor 1" to "Professor 9". Codes are indicated at the end of quotes in square brackets. The acronym "GMM" indicates my questions and interventions.

[79] Knowing the projects considered in this research, it may have been possible otherwise to identify respondents, who were granted anonymity. Transcripts are stored according to the procedures mentioned in the Information and Consent Sheet.

[80] See Robson (2011) and Silverman (2005 pp. 154–155). Also referred to as first and second level coding (Miles and Huberman, 1984).

The conditions and purposes for data collection and management have been explained to participants; particularly for semi-structured interviews signature of Information and Consent Sheets was required. Anonymity, planned in order to encourage honest replies on educational contents and opinions, was used as a general rule. When participants provided contact details and expressed interest in being further involved, confidentiality was granted. As this research involved a range of different geographical, socioeconomical and cultural contexts, I considered different sensitivities in countries when approaching participants for questionnaires surveys and interviews. Data was managed according to guidelines of specific projects; the Board of Ethics of the University of Bradford; Sandia's Human Subject Research Board when applicable interpreted in a restrictive way;[81] and/or if they were already been reviewed and approved for publication. There was no potential harm to participants envisaged from their participation in the projects or the research.[82] Furthermore there could have been the possibility of, in some cases, configuring a dependent relationship between some participants and the researcher. Measures to mitigate these risks included inviting professors to not force students to participate in questionnaire surveys or educational interventions, and explaining to both students and professors that there were no "desirable" answers to the questions in data gathering. Finally, and generally, I tried to uphold high professional standards for reporting and discussing results.[83]

[81] As results are not considered generalizable to larger populations than those surveyed; and they do not identify specific individuals, organizations, institutions or countries.

[82] Given the subject of the research, and potential security risks, a remote but existing possibility was to find situations that were unsecure, unsafe or illegal under national or international guidelines and laws. This could have potentially put colleagues and me in a "whistle-blowing" dilemma (Robson, 2011 p. 219) of deciding to report such situations, possibly causing problems to participants to the research. No such situation arose in the research, and when minor (or general, rather than critical) issues were identified, participants were eager to discuss potential solutions as well as to engage with their generally collaborative management and leadership. However, should major issues have been encountered, whistle-blowing should have been seen as a duty of the researchers, and reporting to competent authorities something eventually helping a more secure context for the participants.

[83] Including accuracy and comprehensiveness in data reporting, avoid over-interpretations from data, and make explicit errors or problems (Sarantakos, 1999).

1.10 Structure of the thesis

While this Chapter presented the research scope and methodological approaches, the next one discusses the theoretical framework informing it. Together, the two Chapters provide the framework used by this research to investigate education as a potential tool to mitigate deliberate disease risks. The next Chapter discusses the social constructionist approach; implications of research on security and disease; approaches of securitization and discourse analysis; concepts of risk; theories from educational science (in particular the ADDIE model of ISD; the learning-by-design and the learner-centred-delivery pillars for education; and the four-levels model of evaluating impacts of education); and the concept of the web of prevention in which education could be inserted.

Applying that outline, Chapter 3 starts the discussion from the conceptual area of risk. It discusses an assessment of the risks of deliberate disease going through risk identification, risk characterization, and factors that have a role in risk evaluation. It identifies three risk scenarios of deliberate disease risks and it discusses if and how education could potentially lower those risks.

Chapter 4 deals primarily with securitization analysis of education as a security tool, and focuses on the first research question. It explains how education has been co-opted by security actors as a strand of the web of prevention and presents an overview of attempted securitization moves on education. Calls for education are analysed and evaluated applying the historico-political securitization approach described in Chapter 2. Finally, open questions on education as a security tool are discussed.

As Chapters 3 and 4 focus primarily on the conceptual areas of risk and security, and present the application of two strands of the theoretical framework, Chapters 5 to 9 focus on the conceptual area of learning and the second and third research questions, applying the third strand of the theoretical framework with the selected methods from educational science.

Chapters 5 to 9 are organized along the phases of the ADDIE cycle for both the education and the instruction design plans of research. Chapter 5 deals with Analysis and, after an overview of results from literature before 2011, presents data from projects on demographics of student learner populations; their mastery of contents relevant for deliberate disease risks; existing educational opportunities; educators' experience and mastery of relevant contents; perceptions and assessments of deliberate disease risks; attitudes and opinions on the importance and the role of education, and on challenges and strategies for implementation.

Chapter 6 focuses on Design, firstly identifying learning objectives on the education and the instruction design plans of research. Subsequently, the Chapter presents instructional design tools used to match objectives with Analysis information, as well as examples of designed education on biorisks (including deliberate disease risks) from considered projects. Finally the Chapter addresses the design of proposed strategies for evaluation of education to mitigate deliberate disease risks in the education and instruction design plans of research, proposing specific evaluation tools.

Chapter 7 discusses the Development and Implementation phases within the ADDIE model of ISD for education to mitigate deliberate disease risks. The Development phase consists in preparing instructional material needed to realize the educational programme; while the Implementation phase consists in carrying instruction to students according to Design and using the developed materials. The Chapter presents guidelines on Development that retain the learning-by-design and learner-centered delivery pillars, as well as examples of practical applications taken from, and informed by, experience from the projects.

Chapters 8 and 9 describe data and experiences from the projects in relation to the evaluation tools presented in Chapter 6, to understand how education on deliberate disease risks could be evaluated after instruction has been implemented. Chapter 8 discusses Evaluation on the education plan of research and if and how education could influence assessed deliberate disease risks in the three risk scenarios. Chapter 9 discusses Evaluation in the instruction design plan and if and how instructional design based on the learning-by-design and learner-centred-delivery pillars could be useful in promoting examples of effective education on deliberate disease risks.

Chapter 10 provides an overview of the themes and findings of the thesis, discusses what contributions it had made to knowledge, reviews the research questions, the research's limitations as well as opportunities for further research.

2. Theoretical Framework

This Chapter presents and discusses the theoretical framework informing the research. The first section presents the social constructionist approach and its application in the research. The second section presents implications of doing research on security and disease. The third section discusses different approaches to securitization, how it has been applied to public health and biology, and key aspects of discourse analysis relevant for the securitization of deliberate disease and the construction of education as a security risk mitigation tool. The fourth section discusses the conceptualization and approaches to risk and the application of a mitigated constructivist stance to risk. Section five presents the theories from educational science used in the research. The sixth section describes the web of prevention as the framework where education would be placed as a security risk mitigation tool. The last section summarizes the theoretical framework choices.

2.1 An application of the social constructionist approach

Concepts of social constructionism and their application to studying the relations among security, life sciences, disease and risk, are vital for the design of this research. The constructivist approach in security studies is largely based on its application to international relations (Agius, 2013) by Onuf (1989), itself based on the social constructionist and constructivist tradition in social science (Burr, 2015). [84] According to social constructionism and constructivism, social entities and properties are fabricated (constructed) through interactions among people and groups, and those entities and properties can be only known through interaction regardless of a possible "objective" reality. [85] Ontologically, constructivist

[84] The constructivist approach in international relations sustains the importance of identities for international political action and decision-making, and that reality(ies) and ideas are socially constructed (Reus-Smit, 2005), as well as the central role of beliefs, cultures and norms (Agius, 2013). Ruggie (1998) contends that rather than a theory of international relations, constructivism in the field should be seen as a "theoretically informed approach to the study of international relations".

[85] Social "constructionism" usually identifies approaches that describe interactions among groups, while "constructivism" would more often identify theoretical approaches looking at individuals (rather than groups) actively creating their own meanings (Robson, 2011; Burr, 2015).

research generally opposes positivism and empiricism[86], and contests the notion of objective reality. Epistemologically, according to constructivists all knowledge is relative (Burr, 2015), and the focus cannot be on "reality" but rather on how the world is represented, described and made to appear real (Holstein and Miller, 2006).[87] The extent to which constructionist researchers view reality as "real" varies, with degrees between relativism and realism.[88] Other differences include at least one on ontological stances between "strong" (also referred to as "light" or "micro") constructionism focusing on language structures, and "weak" (also referred to as "macro") constructionism focusing on the role of social structures utilizing language to shape the world, as well as being shaped by language (Burr, 2015).[89] Common traits, however, include always keeping a sceptical stance towards claims of truth, including the researchers' own, and the stress on the role of language[90] in shaping representations of the world, if not the world itself. "Micro" social constructionists study language in the everyday interactions of individuals

[86] "The belief that we can only know what we can immediately apprehend. That which exists is what we perceive to exist" (Burr, 2015 pos. 4452) and "the view that the only valid knowledge is that which is derived from observation and experiment" (Burr, 2015 pos. 4425), respectively

[87] Ontology regards how we consider the nature of the (social) world (Robson, 2011) and the assumptions we make on the social entities (Jabri, 2006). Epistemology regards how we consider the nature of knowledge, how we create knowledge about the world (Robson, 2011), and if and how we can understand social realities. Every research has ontological and epistemological foundations depending on the researcher's beliefs, the researched subject, and the context of the research. These foundations influence the research design as well as its tools and claims of any "result".

[88] Relativism argues that reality, if it exists, is inaccessible, and that any representation of the world cannot be checked for "accuracy" against it. Hence, no account can be preferred as "truer" than another. Realism posits that the (an) external world exists independently from the social actors that interact with it, and with properties that are given and do no change based on different descriptions or interpretations. Reality exists, and while descriptions are not necessarily able to depict it, it at least underpins them (Burr, 2015). Social constructionists accepting some tenets of realism are often considered closer to critical realism, according to which real structures and cause-and-effect relations exists, even if they are not always observable or measurable. Research can however infer them through analysing the effects and try to unveil structures, assumptions and consequences possibly to the benefit of people.

[89] Furthermore, epistemological differences include that modern constructivists believe that a positivist epistemology can be used to analyse, describe and explain constructed reality, while post-modern constructivists are more radically interpretivist in refusing firm concepts of reality and the possibility of explanation (Reus-Smit, 2005).

[90] Broadly including not only speech and text, but also any representation and form of communication.

constructing different, “personal”, views of the world.[91] For “macro” social constructionists, on the other hand, language not only constructs but is also used to support, challenge or enforce social structures, relations and practices. In this sense and especially in the poststructuralist vein of macro constructionism, language is connected with competition and power. For both approaches, “discourse” is a central concept and tool of language, but for macro constructionists it extends beyond just the contingent speech or text. According to approaches derived from the work of Foucault,[92] discourses are all “practices that systematically form the objects of which they speak” (Foucault, 2002 p. 54), combinations of meanings, attributes, representations that create versions of reality. Mobilizing language, discourses create competing knowledge, and hence are also instruments of power. One of the main lines of argumentation in the thesis advances that discourses can be, and are, used to depict (at least certain aspects of) life and associated sciences and technologies in terms of security and insecurity, of generating “risks”, be associated with “threats”, requiring security “measures”, and that new areas such as education became constructed as instruments of security.

I will maintain some inputs of the micro, or strong, constructionism, for example in the application of securitization analysis,[93] that are very much linked to the idea of language as action-oriented and creating performative acts (Burr, 2015). However, my approach is mostly with macro, or weak, constructionist. A first reason is that categories of security, risk and disease will be discussed in the perspective of how they are constructed by competing discourses. Secondly, discourses are regarded as attempted moves of protection by different groups such as governments, civil society

[91] Examples including the work of discursive psychologists, which studies how people “put their linguistic skills to use in building specific accounts of events, accounts which may have powerful implications for the interactants themselves. It is therefore primarily concerned with the performative functions of language” (Burr, 2015 pos. 400).

[92] In Michel Foucault’s view, philosophy is the “politics of truth”, and truth is always the winning result of a power struggle (Foucault and Napoli, 2005 p. 14). The exercise of power determines what position or, using a Foucaultian category, discourse, will be validated to constitute “true knowledge” and rule out other positions (Mills, 2003). Discourse is also what informs and shapes, through its procedures, knowledge.

[93] Yet with a critically applied alternative approach to securitization analysis, that makes it closer to the general macro stance of the research, as detailed below.

and the scientific community. Securitization, risk assessment and management, as well as education, can all be described as discourses that suggest or prescribe what should or should not, can or cannot, be done. Thirdly, and especially in relation to the conceptualization of risk, I assume that ontologically and epistemologically speaking there can be a “relatively objective” (in the sense of comparable, because of its relativeness) analysis. At the same time I maintain the sceptical constructivist stance to truths, including any that could be suggested by my own analysis. The main concepts interacting in the research, including security, risk and learning, will be presented as different actors have constructed them[94] and how they are constructed by the research itself in possible, non-exclusive, meanings. World-views borrowed from traditionally empiricist, if not realist, approaches such as risk management will be re-presented to uncover their actual components of relativity and subjectivity and integrated in the macro (weak) social constructionist approach.

2.2 Security, life science and disease

Investigating deliberate disease raises fundamental ontological, epistemological and methodological challenges to the research.[95] Such challenges derive from the complexity of the contested concept of security and are reflected throughout the security discourse. On one side there are traditional approaches which tend to be identified with political realism, a positivist epistemology, a focus on the military dimension, and the consideration of states as the main, if not exclusive, referent objects and actors of security (Smith, 2005). On the other side, there are approaches that have flourished as reactions to the theoretical and methodological limitations of traditional approaches. Alternative approaches to security refute, to varying degrees, positivist explanations, and are more or less accepting of constructivist accounts and interpretations.[96]

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[94] Not least considering their social context and identities.

[95] Not only ontology and epistemology approaches influence each other, but they also have a bearing and are affected by research methodology, that has been described in Chapter 1.

[96] According to constructivist security studies, there is no objective security reality, so security categories such as actors, referent objects and issue areas are mutually created by the relationships of the social actors (Agius, 2013). As such, ideas and norms can be changed and promoted.

The most important differences of alternative security studies approaches from traditional approaches [97] are firstly the recognition that other phenomena, besides states, are relevant for security, and secondly, that so is the move to widen the scope of security studies beyond the military dimension, what Booth (2005) has termed respectively the deepening and the broadening of security. [98] Rothschild (1995 p. 55) has depicted broadening security as extending the referent objects from nation-states to individuals, groups, society as well as the biosphere; actors of security from nation-states to international organizations, NGOs, interested individuals and public opinion; and dimensions of security from military to political, economic, social, environmental and human.[99]

Regarding security and disease, Fidler and colleagues (Fidler, 2007a; Fidler, 2007b) discussed the evolution of the relationship between security and public health and, even recognizing that already in 1983 Ullman proposed an *ante litteram* definition of human security that included among risks “decimating epidemics” (Ullman, 1983 p. 133), they explained that the convergence between public health and security that would be accepted by “experts” on both sides is much more recent. This would imply that public health migrated from “low politics” to the “high politics” areas (Booth, 2005 p. 7) considered by security studies. Indeed, traditionally these studies paid little attention to security issues related to

[97] And indeed what makes possible to apply them to the investigation of relationships among science, life and security.

[98] According to Booth, deepening security studies means looking at “a more extensive set of referents for security than the sovereign state, from individuals to the whole of humanity” (Booth, 2005 p. 14). Broadening would entail expanding security studies to issue areas beyond the military one.

[99] The development of the human security concept is particularly relevant for the broadening of security studies. This concept emerged in the early 1990s largely thanks to the promotion by the United Nations Development Program as protection of people from both long-term threats and sudden disruption of daily life conditions. Supported by other multilateral developments (such as the use of the term by the United Nations and NGOs alike, and the UN Secretary General and Security Council being involved in “broadened security” via human security), the paradigm had increasing fortune describing the evolving security needs in the post Cold-War era. Pereira (2008) summarized characteristics of human security in being emancipatory, pacifist and human rights centred. Human security proponents embraced the deepening and broadening of security paradigms possibly before their formal theorization, and one of the issue areas that were more strongly introduced was that of public health and disease.

public health. According to Fidler and Gostin, the constitution of the WHO in 1948 was an initial shift from the purely realist[100] positions of states protecting their own trade interests, to the consideration of people's health conditions as rights. However, despite the development of international public health, this did not have an impact on how states saw security. The two policy worlds only collided in the early 21st century, and because of factors the authors present as exogenous and objective: "dramatic developments" (Fidler and Gostin, 2008 p. 136) in the threats of a changing context that shaped new policies. Among these, primarily were the terrorist attacks of September 11th, 2001 and the subsequent bioterrorism events, and secondarily the salience of naturally occurring disease problems such as SARS, avian flu outbreaks and the development of microbial resistance. The authors maintain that infectious diseases were characterized as a security problem, and a novel link between security and public health was created. Public health also became a tool in domestic and international security policies: the 2002 national security strategy in the US (White House, 2002), the United Nations Secretary General High Level Panel on Threats, Challenges and Change (United Nations, 2004), and the 2005 edition of the WHO International Health Regulations (WHO, 2005), all mentioned the role of public health to ensure security and would be examples of this integration.

Deepening, broadening and converging of security also presents potential problems. It has been noted that broadening security could result in "making security studies too amorphous" (Morgan, 1999 p. 64), or diluting the important military dimension of international and global security (Ayoob, 1997). However, if we accept that there are security issues linked to the life sciences including the potential for deliberate disease, we may follow Krause and Williams' point when they say that "it may be necessary to broaden the agenda of security studies (theoretically and methodologically) in order to narrow down the agenda of *security*" (Fierke, 1997 p. 249, emphasis in the original), in order to be able, on the one

[100] The "realism family" of theories of international relations in its basic common elements posits that states are the key, rational, actors in an anarchic – though not chaotic – international system; and power (mainly in its military form) as the main defining feature of inter-state relations (Glaser 2013).

hand, to consider all relevant aspects of contemporary security issues, but on the other hand to analyse specific issues and assign appropriate roles and responsibilities to the extended range of security actors involved – not only states and international organizations, but also scientists and civil society.

2.3 Biosecurity, biosafety and biorisk management

Issues related with security and disease are often presented as lying along spectra. One spectrum is the source of harm and would include natural outbreaks of infectious diseases, chronic diseases, accidental contamination or release of (dangerous) biological materials, unexpected consequences of research and of application of life sciences, and deliberate harm caused (by people) using (dangerous) biological materials (i.e., deliberate disease). Another spectrum looks at the causative agent of harm: infective pathogenic agents (virus, bacteria, fungi, rickettsia), chemicals with effects on biological systems like bioregulators (Bokan and Orahovec, 2004), toxins produced by biological organisms, living genetically modified organisms, invasive animal or plant species. A third spectrum would be potential consequences: death, incapacitation, injuries, material destruction, economic loss, and psychological stress.[101] The 2013 Global Risks Report of the World Economic Forum considered "vulnerability to pandemics"[102] and introduced "unforeseen consequences of new life science technologies"[103] in its yearly risk landscape analysis (World Economic Forum, 2013). In this research, I primarily focus on deliberate disease risks. However, it appears important to understand how issues are, in some cases, connected both in terms of challenges and security measures; and to consider the relative importance, perceptions, and responses regarding deliberate disease compared to the other issues

[101] Life sciences and biotechnology are also present at different sides of the security risk equation: they can be referent objects (i.e. to ensure people's survival and safety from harm, science and health have to be preserved), sources of harm (i.e. biological agents or potentially misused scientific research or technological applications), and security tools (to prevent, mitigate and respond to harm).

[102] Described as "inadequate disease surveillance systems, failed international coordination and the lack of vaccine production capacity".

[103] Described as "advances in genetics and synthetic biology produce unintended consequences, mishaps or are used as weapons".

outlined above, within the security policy, life science, and civil society communities.

Overlaps between different conceptualizations and boundaries attributed to security issues related to life sciences, biotechnology and public health are epitomized by the analysis of the term biosecurity. As the composite word may suggest, biosecurity could refer in general to “security related to living organisms”, and in this sense it would generally represent security issues related to biology. However, the term evolved in parallel in different contexts and is used with different meanings in different fields such as animal health, agriculture, ecology, food supply, public health, laboratory management and arms control. FAO describes biosecurity as a “strategic and integrated approach” comprising policy and regulatory measures that “analyse and manage risks in the sectors of food safety, animal life and health, and plant life and health, including associated environmental risk. Biosecurity covers the introduction of plant pests, animal pests and diseases, zoonoses, the introduction and release of genetically modified organisms and their products, and the introduction and management of invasive alien species and genotypes” (FAO, 2016). Some countries use biosecurity in the same context, even if narrowing its focus on the protection from particular biological sources of harm. New Zealand’s biosecurity system, for example, aims to “keep out, remove, or effectively manage the harm that pests or diseases can do to our economy, the environment and our health” (New Zealand, 2016); similarly Australia sees biosecurity as the protection of “the country from exotic pests and diseases through quarantine, surveillance, and detection” (BTWC, 2003a p. 125, statement by Australia). Generally, the veterinary and agriculture meaning of biosecurity has come to denote the protection of national biological resources from foreign or invasive biological agents. This conceptualization of biosecurity does not distinguish between accidental or intentional acts, focuses on selected biological agents as potential sources of harm, does not distinguish between pathogens and other biological agents, and comprises technical, policy and regulatory measures. An alternative interpretation of biosecurity has been offered by the WHO, which in the third edition of its Laboratory Biosafety Manual defined biosecurity in the public health context as the “protection of microbiological assets from theft, loss, or diversion which could lead to the inappropriate use of these agents to cause harm" (WHO, 2004). This conceptualization of biosecurity focuses on people as potential sources of harm, on the intentional nature of the unwanted events, on one subset of biological agents, and comprises both technical and public health policy measures. The concept has been further specified by the WHO, restricting the use of the word to laboratory environments. Laboratory biosecurity is defined as "the protection, control and accountability for valuable biological materials within laboratories, in order to prevent their unauthorized access, loss, theft, misuse, diversion or intentional release" (WHO, 2006). Laboratory biosecurity focuses on the prevention of intentional acts; several types of biological materials such as pathogens, toxins, pharmaceutical products, food products, GMOs, non-pathogenic microorganisms, extraterrestrial samples, genetic materials and radiolabelled biological material; and both technical and procedural measures, but limited to the laboratory environment. Laboratory biosecurity measures have been further described as comprising five categories: physical security, personnel security, material control & accountability, and program management elements (Salerno and Gaudioso, 2007). The boundaries of the laboratory environment have been relaxed with the approach of the OECD, which developed biosecurity guidelines for Biological Resource Centers (BRCs) (OECD, 2007), defined as "service providers and repositories of the living cells, genomes of organisms, and information relating to heredity and the functions of biological systems.[104] In the context of the BTWC, biosecurity is mostly used to refer to measures to maintain security and oversight of pathogenic organisms and toxins, not necessarily limiting to laboratories (or BRCs), but generally regarding all work with relevant materials that could be used for purposes prohibited by the Convention. Discussions of this concept took place in the first year of the first Inter-Sessional Process (ISP) in 2003, which included among topics of discussion "national mechanisms to establish and maintain the security and oversight of

[104] BRCs contain collections of culturable organisms (e.g. micro-organisms, plant, animal and human cells), replicable parts of these (e.g. genomes, plasmids, viruses, cDNAs), viable but not yet culturable organisms cells and tissues, as well as data bases containing molecular, physiological and structural information relevant to these collections and related bioinformatics" (OECD, 2001).

pathogenic micro-organisms and toxins". On that occasion, some States Parties already used the term biosecurity (or bio-security), however in some cases underlining how a unique and clear-cut use of the term was not yet achieved, and how biosecurity was still an evolving concept (BTWC, 2003b). States Parties noted their common understanding that in the context of the Convention biosecurity refers to "the protection, control and accountability measures implemented to prevent the loss, theft, misuse, diversion or intentional release of biological agents and toxins and related resources as well as unauthorized access to, retention or transfer of such material" (BTWC, 2008b p. 10).[105] Furthermore, while in the context of the BTWC the difference of the conceptualization is marked from the other foci, the different meanings can still connect and overlap.[106] The conceptualization of biosecurity in the context of the BTWC focuses on the prevention of intentional or unauthorized acts, biological agents (mainly, but not only, pathogens) and toxins, legislative, procedural and technical measures, and including but not limited to the laboratory dimension.

Biosecurity, especially in those conceptualizations that underline the prevention of intentional acts, is also distinguished but closely related to biosafety. This term also experiences different meanings in different contexts, however they are more established in indicating two alternative concepts. The first one regards regulation, containment and prevention of undesired effects of GMOs, such as in the context of the Cartagena Protocol on Biosafety to the Convention on Biological Diversity, which defines biosafety as "efforts to reduce and eliminate the potential risks resulting from biotechnology and its products" (Convention on Biological Diversity, 2016). The second concept is in the context of public health and defined by the WHO as "the containment principles, technologies and

[105] States Parties made clear this should not be considered a definition, recognizing the competing meanings used in several countries (BTWC, 2008a).

[106] As Brazil (Brazil, 2008) stated, the lack of agriculture or veterinary biosecurity "could lead, by means of criminal insertion of such foreign and/or invasive species, to the intentional destruction of crops and/or livestock, with deleterious effects not only to the economy but also - and most importantly - to food security around the globe. These concerns are related to the concepts of bioterrorism and biopiracy, which are also of relevance to the BWC. It is the Brazilian view, therefore, that the excessive narrowing of the definition of biosecurity should be avoided".

practices that are implemented to prevent the unintentional exposure to pathogens and toxins, or their accidental release" (WHO, 2004). States Parties to the BTWC also considered the latter understanding of biosafety as relevant to the Convention, adopting a slightly enlarged definition that uses "biological agents" instead of "pathogens" (BTWC, 2008b). A recognized issue for definitions has been to achieve clarity on how biosafety and biosecurity are distinguished but connected, concerning respectively unintentional/accidental and intentional events. Common understanding is complicated by the fact that several languages do not have the same distinction among the "security" and "safety" terms as in English. [107] One effort to overcome these issues has been the conceptualization of a framework that integrates biosafety and biosecurity, recognizing that some measures are common to address both accidental and intentional events, as in the case of biorisk management. Biorisk management has been particularly codified in the context of managing safety and security risks in the laboratory environment, especially with guidelines issued by the Comité Européen de Normalisation in 2008 and renewed in 2011 (CEN, 2011); however management of both safety and security biological risks can be addressed with assessment and mitigation measures that go beyond the laboratory.

The concept of biosecurity hence has evolved in parallel to the conceptualization of agricultural and biodiversity contamination, using the focus on intentional threats. Initially this debate was limited to theft and unauthorized access and subsequently expanded to intentional misuse (Koblentz, 2009). In parallel to this process, measures evolved from a focus on the laboratory dimension to a multilevel and multidisciplinary rubric going beyond the doors of biological facilities. Biosecurity will be addressed in the context of this research in its "broader" concept within the idea of preventing deliberate disease. This choice espouses the multilevel

[107] Many romance languages such as Spanish (Cuba, 2008) and Italian, for example, use the same term for both concepts which may be mirrored in national implementation measures or institutions addressing prevention of biological harm of either accidental or intentional nature, and/or from pathogens, GMOs or invasive species. In some cases, such as French (France, 2008), Portuguese or Arabic, two different terms are used at the regulatory level, but only one term is used in the common practice of scientific or health sectors.

idea of biosecurity and is located conceptually in the context of the so-called web of prevention described later as a set of measures to prevent the multifaceted constructed risks of deliberate disease. Not only is it a component of the web, biosecurity is also a web in itself containing complementary stands of mitigation integrated into the range of measures and dimensions that make up the wider mitigation structure.

2.4 Securitization and deliberate disease

In the analysis and construction of educational messages, this research will leverage a critical application of securitization studies. The model was originally proposed by a group of scholars known as (Smith, 2005; Sheperd, 2013) the Copenhagen School, including Barry Buzan, Ole Waever and Jaap de Wilde, that here will also be referred as the "traditional" securitization model. Securitization studies have a constructivist discourse analysis approach, described by Waever (1995) and integrated into a more general framework sketched by Buzan (Buzan, 1991, Buzan et al., 1998). According to them, securitization occurs when a securitizing actor successfully performs a securitization move, i.e. proposes a discourse that, with a specific rhetoric structure, presents an issue as an existential threat to an audience who accepts it. The process of securitization builds on the concept of speech act (Austin, 1962; Potter and Wetherell, 1987), an utterance that constitutes an act in itself, that by saying something, does something and has concrete consequences.[108]

2.4.1 The traditional securitization model

According to the securitization model, the securitization speech act would be a performative speech act having four constituent elements which "must be met for a successful securitization to occur: a) securitizing actors must declare a b) referent object to be existentially threatened and must make a persuasive call for the adoption of c) emergency measures to counter the threat and d) the audience must then also accept that argument to a sufficient degree for it to become possible to do things

[108] Like naming a ship, declaring war, declaring a state of emergency. Austin explains that any sentence can convey one of three types of acts: a locutionary speech gives sense and reference to a performing act; an illocutionary sentence is one performed during the act; and a perlocutionary sentence aims to evoke in the audience specific acts. Onuf (1998 pp. 66–8) also addressed the category of speech act and identified three types: *assertions*, that relate to knowledge about the world; *directives* that give instructions; and *commitments* that imply promises.

politically that would not have otherwise been possible to do under normal or routine political conditions" (Buzan et al., 1998 p. 36).[109] Saying "security",[110] is the traditional method used by the authority to designate emergency, which implies the possibility of using exceptional means and the suspension of normal practices, as an issue is presented as "more important than other issues and should take absolute priority" (Buzan et al., 1998 p. 24). According to the Copenhagen School, any policy issue can lie (and be moved) along a continuum that includes non-politicization, politicization - becoming "part of public policy, requiring government decision and resource allocation" (Buzan et al., 1998 p. 23) - and securitization. For the Copenhagen School, the security utterance is the security act itself: the conditions of possibility of a reality of security are "constitutive of the speech act of saying 'security'" (Waever, 1995). Security analysis is really discourse analysis, as the attention is on the speech acts and their messages of existential threats and urgency, and on the acceptance by the audience(s). As such, there are not *objective* security threats; however, security is also not purely subjective, because it is the result of interaction between the involved actors: "securitization, like politicization, is intersubjective" (Buzan et al., 1998 p. 30).

The Copenhagen School regards security as a socially constructed concept (Emmers, 2013) and with a primarily constructivist approach (Balzacq, 2010). Scholars of the Copenhagen School are "broadeners", and proposed the expansion of security studies to four new sectors (environmental, economic, societal, political) (Buzan, 1991), however maintaining a structured division of issue areas as well as a distinct attention to the military sector. The most traditional part of their approach regards referent objects and actors of security. While Buzan (Buzan, 1991) criticises hard divisions between individuals, states and the international system, he still sees states as major referent objects and actors of international security. Later, states are still the objects of security discourses, but the "middle scale of limited collectivities" (Buzan et al., 1998 p. 39) is presented as an ideal securitisable unit. On securitizing

[109] Applying Onuf's reasoning, a securitization speech act would be *assertive*, and a successful one (i.e. one that is accepted by its audience) would also be *directing* and *committing*.

[110] And applying the relevant rhetorical categories, such as those of survival, priority, urgency.

actors, the primacy of states is maintained, with pragmatic reasons before ideological ones: “some actors are placed in positions of power by virtue of being generally accepted voices of security” (Buzan et al., 1998 p. 39), but other common players are also accepted including pressure groups, as long as they can be seen as authoritative speakers by their audiences. They also believe that “even the socially constructed is often sedimented and becomes so relatively stable as practice” (Buzan et al., 1998 p. 35); eventually what is important for the securitisation analysis is its practice, not the actors.

In this research, states, scientists and civil society are regarded as potential securitising actors; and life sciences and technology are framed as both potential referent objects and potential source of risks, even if our sector of analysis is not explicitly included among Copenhagen School’s security issue areas. However, not only its authors recognize that issues as diverse as religion or culture have been securitized in some cases, but others have extensively applied securitization studies to science and public health.

2.4.2 Alternative securitization models

Alternative applications of securitization have been proposed. Balzacq (2010) criticizes the traditional model, that he labels “philosophical approach” to securitization and thinks it is actually post-structuralism focusing too much on the text of the securitization move. According to him, securitization should really focus on perlocutory (performative) speech acts as it tries to stimulate responses from the audience.[111] Balzacq underlines what he sees as inconsistencies between the philosophical approach and, on the one side, the post-structuralist methods of analysing security that it ends up using and, on the other side, social modern constructivism that should use an anti-essentialist ontology and a positivist epistemology. In opposition, Balzacq proposes what he calls a “pragmatic” or “sociological” model of securitization, which would consistently base on constructivism not having to “hide” post-structuralist methods, rather “blending discourse analysis and process tracing” (Balzacq, 2010 p. 3).

[111] According to this vision, what the Copenhagen School’s approach has overlooked, as a pathological consequence of the focus on the practice rather than the actors, is the audience and the context.

According to this “sociological” securitization approach, and moving towards a more macro constructionist approach of securitization analysis, security is influenced by discourse but it’s more than a mere speech act, it’s rather a pragmatic act, i.e. “a sustained argumentative practice aimed at convincing a target audience to accept the claim that a specific development is threatening enough to deserve an immediate policy to curb it” (Balzacq, 2010 p. 9). Securitization is an “argumentative process” by securitizing actors in the social field; as such the text is sustained by a rationale that will be important in the acceptance by the audience. The analysis hence should look not just at the rhetorical rules but also at the arguments backing the discourse. The context is not just shaped by the speech act but also contributes itself to the decisions of the securitization discourse, which now becomes action and can differently contribute to the securitization discourse if it is, for example, embedded rather than episodical in its environment. The relationship with other discourses on the same subjects, the resulting policy tools and events (and not just the speeches), the routinized narratives, etc. also gain relevance in the process-tracing component of this pragmatic securitization model. Similar critiques have been moved to the traditional securitization model of the Copenhagen School, as that it analyses discourses but does not check if a norm becomes “embedded in bureaucracies, enforced, practically accepted” (Vieira, 2007 p. 139).

2.4.3 Securitization of public health and disease

Contemporary examples of securitization could include terrorism after 9/11 and, in the biological sector, swine flu in the UK in 2009 (Ricci, 2009). Agriculture in the European Union has been successfully securitized against GMOs in the early 2000s (European Union, 2001), while later the discourse on the “existential threat” has been relaxed (European Commission, 2010a). Victims of toxic weapons have been securitized in Syria by the United States government establishing the “red line” of biological or chemical weapons use (DeYoung and Gearan, 2012). Applications of the securitization framework occurred in literature on public health issues, including naturally occurring and deliberate disease or consequences of potential misuse of life sciences, which obviously analysed (and maybe contributed?) to the convergence between public health and security. Kelle (Kelle, 2005a; 2005b; 2005c; 2007a) analysed the process of securitization of public health at the global level and in five countries. He described how, on the one hand, terminology traditionally used for Weapons of Mass Destruction (WMD) was gradually associated with infectious disease starting from the 1990s and, on the other hand, public health became increasingly quoted by security policies as one necessary tool to defend from deliberate disease. Kelle explicitly referred to the Copenhagen School as the model for securitization studies.[112] However, and more in line with the alternatives to the traditional securitization theory described above, Kelle, rather than the textual force of the statements, looked at their related action and the relationships between narratives and the pragmatic impact in their context, in some cases describing threats as historical events and seemingly contributing to the same construction of securitization messages besides their analysis. Another analysis on securitization and public health came from Fidler, who proposed that international health already entered a securitized phase where "the policy belief that public health can be improved by framing and approaching problems through security-related tactics and strategies has become a leading driver of public health performance" (Fidler, 2007b p. 41). Fidler (2007b) explains his view on how prevention, protection and response to humanitarian catastrophes (including international health assistance) has been shifting from an approach based on peoples' rights to wellbeing to one based on security. Fidler presents some of the disastrous threats addressed by securitization as not just the product of intersubjective construction: according to him, the three main threats are CBRN weapons; infectious diseases; and (other) natural disasters. In his analysis, the referent objects of securitization are "individuals and societies", and he introduces the concept of securitism, which is a prerequisite for the securitizing actor: "the belief that framing an issue as a security threat can lead to more political attention, economic resources and policy action" (Fidler, 2007a). Fidler and Gostin (2008) describe as

[112] And he included in his reviews the analysis of relevant discourse sources (securitizing actors) such as, *inter alia*, declarations from the World Health Organization, statements to meetings of the Biological and Toxin Weapons Convention, US Department of State policy documents and Centers for Disease Control reports, texts of legislation of the countries considered

novel the "shift" in policy that brought public health and security – both "quintessential public goods" - closer, and identified the cause of securitization in the constructed (but, to some extent, still presented as "exogenous") new threat of biological weapons and bioterrorism, and then expanded to natural infectious diseases; the authors describe a "dual-use securitization" that brings improvements to the management of both natural and deliberate disease threats (Fidler and Gostin, 2008 p. 124). The authors underline how securitization of public health has moved it out of humanitarianism (as such often neglected) to the area of national and international security. An increasing interest on international assistance in the last two decades would be due to the fear of bioterrorism and infectious diseases threats (now security matters) rather than to a humanitarian response.

Other scholars contributed to the theorization of securitization of public health as response to the disease threat (Elbe, 2010; Leboeuf and Broughton, 2008). Vieira (2007) looks at the global discourse since the late 1990s on the HIV/AIDS epidemic as the construction of an international securitization norm that presents HIV/AIDS not (only) as an infectious disease but as an emerging threat to international peace and stability. Vieira analyses the rhetorical practices of the discourses of promoters of the HIV securitization norm; however, he also joins the critics on how the Copenhagen School overlooks context. Indeed the "semantic articulation of security should be analytically integrated with the larger process of securitization that involved social/political phenomena other than solely the speech act" (Vieira, 2007 p. 153). He goes further in reprising Elbe (2005) who, on the construction of HIV/AIDS as a security threat, had considered the Foucaultian [113] view of biopolitics and

[113] As in many other fields of social science, Foucault's philosophy has also been used in security studies, recognizing that he detected "new figures of truth in the early history of the political modern, especially in its mechanisms of power and in how new problematisations of politics were allied to new security problems" (Dillon and Neal, 2011 p. 3). Foucault dealt directly with issues of security at the political and societal levels and analysed it in relation to the penal system, discipline and risk. His focus on security is however also disputed (Bigo, 2008) as Foucault's "*dispositifs de sécurité*" have not only to do with coercion and discipline but are also a feature of liberty, mechanisms used to ensure circulation and operationalization of life, distinguishing modern "*sécurité*" (security of population and life) from the ancient "*sûreté*" (safety of the prince and territory). To use the French

biopower. [114] Both authors advance the contention that adding the biopolitical dimension to securitization of HIV/AIDS helps in addressing the limitations on context and securitizing actors of the traditional securitization school. The transposition of biopower to securitization "allows for an holistic understanding of the securitization process. This process is not the act of one securitizing actor but a chain of events and actors and something that historically mutates and evolves into something else" (Vieira, 2007 p. 154). Vieira's conclusion, using this biopolitical approach to securitization of HIV, is that "the historical and social construction of the

term is interesting not only as an etymological exercise, as the difference will resurface when we'll deal with the competing terms of biosafety and biosecurity, chance and intention, and their translations between different languages as well as the technical and political communities.

[114] Foucault explains (Foucault and Zini, 2005) how since the XVIII century, the object of government moved from goods and individuals (people) to the population. This shift is linked with the rise of liberalism that changed the jurisdictional scope of government of *raison d'état* and self-perpetuation, to the external 'bio-economical' objective of protecting the new subject of civil society (Foucault and Zini, 2005 p. 262). Increasingly, power dealt with, and regulated issues of, living beings in the population, and life became the issue at stake for politics, establishing biopolitics. Biopolitics is really how the new governmental issues of liberal societies constituted by groups of beings joint in populations have been addressed, and is strictly connected with the rise of the civil society as an intermediate actor between economy and public law. Biopower is the active force that shapes, modifies and directs life, and normalizes it establishing rules via the biomedical/bioeconomical knowledge (Foucault et al., 2002). The mechanisms of power/knowledge have to work according to the properties of life: to prosper, knowledge needs to reproduce and circulate, and the product of a winning discourse is knowledge that is allowed to circulate, increasing its strength. Foucault's meaning of biopolitics is useful, as we have seen above, in the analysis of securitization of public health, and is particularly interesting to look at the threat of deliberate disease. Biological weapons are "life turned against life" and, in case of infectious diseases, they not only are but also make other living beings bearer of death, by contagion. In this sense, they reverse the biopolitical imperative of making life live promoting circulation. The discourses of biosecurity (the "lock up" of dangerous pathogens) as well as of securitization of public health are also strongly biopolitical. As epidemiology, birth controls, eugenetics, dietary practices or neural enhancement, biosecurity also "makes life the referent object of power relations" (Agamben, 1998). Beyond that, biosecurity follows the biopolitical evolution of security and war, which as Dillon and Neal's (2011 p. 10) commented, has become more focused on life and often conducted "in the name of life itself". Also relevant for the biopolitical analysis of biosecurity as securitization of life sciences, Bruno Latour developed a different concept of biopolitics, that he views as the "authority via which scientists and biologists avoid discussion on scientific disciplines and political life" (Latour, 2005). Latour posits that politics reclaims its power on science as soon as experts touch key nodes of public life – something we see in relation to tensions between security and science communities. Latour also hints on hybridation of nature and culture, between science, politics, economy and technology that constitutes our modernity; and calls himself for hybridation of governance between science and policy (Latour and Lagomarsino, 2009).

disease eventually led to the creation of a hegemonic grammar that portrays the epidemic in terms of a special type of problem which demands special institutions and policies"; and it goes on in the sense that after a grammar successfully becomes hegemonic, to ensure securitization one still needs the practical application of principles and policies – hence the rhetorical speech act and the socially embedded discourse are not enough to ensure securitization; and the analyst should remember to check their applications. This holistic and "socio-political" concept of securitization in public health is further advanced by Pereira (2008) who analyses the securitization of infectious diseases in Western liberal democracies. While recognizing that the topic of infectious diseases has been included in recent strategy and security concepts, Pereira opposes what he labels Fidler's juridical approach to securitization which, according to him, is a limited legalist analysis that doesn't help in understanding who and what is behind the power reordering in speaking (about) public health. Instead, he advances a political, historical and critical version of securitization in which the recent attention to natural and deliberate public health threats is actually the continuation of "three hundred years of Western public health intervention as a global securitizing practice under an assemblage of dispersed and multifaceted, though hierarchized, liberal powers" (Pereira, 2008 p. 12). In this historico-political model of securitization, securitizing actors are not only the traditional governmental élites, but also all those influent agents that can represent authority including NGOs, private companies, networks, influential individuals, and the civil society.[115]

[115] Explicit is again the connection of the historico-political securitization analysis with biopower as a) we look at the securitization of, ultimately, biological bodies of individuals and of biological issues in the society; b) the securitization of infectious diseases indeed "can be traced back to public hygienist surveillance since the 1830s" (Pereira, 2008 p. 8) that inspired Foucault's reasoning on biopower; c) biopower is not exclusive nor concentrated in the state, but diffused "in a comprehensive web of institutions and practices"; d) as a product of liberal democracies, a condition of governamentality is that biopower needs to be justified, hence the importance of the (securitization!) discourse(s); and e) biopower, as in the result of a successfully implemented securitization move on public health, does not only need discourses but also "institutions, architectural forms, regulatory decisions, laws […]" (Pereira, 2008 p. 9).

The securitization analysis framework, and in particular its historico-political approach, has points in common with other Foucaultian categories, within discourse analysis. For Foucault, security is exercised on population and on life; the implementation of *dispositifs de sécurité* is used to reduce the aleatory (Foucault and Napoli, 2005), which includes disease; power determines which discourse will be validated to constitute "true knowledge" and rule out other positions (Mills, 2003). Language, the productive and maintaining force of knowledge (and hence of power), can be a dividing and oppressive tool to exclude discourses that are not aligned with the dominant one, rendering them false. To achieve this, categories and principles of the order of discourse are used, including external and internal procedures of exclusion; restriction systems; and principles of limitation.[116] The modalities to put into action the securitization "threat-defence" sequence, resemble Foucaultian rituals, and in the case of

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[116] The three external procedures of exclusion are imposed *on* the discourse and include *interdits* (prohibitions), *partages* (partitions) and the will of truth. Prohibitions are limitations on who can speak and what can be told, for example taboos and speaking rights. *Partages* include limitations against those whose discourses are not accepted or cannot circulate – such as the mad. Discursive procedures include the necessity of a particular terminology constituting the boundary of a discipline or the authority for a *partage*: in case of epidemics, a bioterrorism attack or a major incident involving toxins, for example, information would be sought by the population from institutions such as the Centre for Disease Control, the World Health Organization or the Federal Bureau of Investigation, depending on the context for authority. The will of truth compels that "true and "strong" discourses can be told by who has the right, and follows the proper ritual, to speak. Scientific progress for example can be read as changing wills of truth. There exist also three internal procedures of exclusion, or "principles of rarefaction" as they distribute, reproduce or limit discourse starting *from* it: they include the commentary, the author and the discipline. The commentary reprises narratives and, while repeating the original text, also adds new information; it limits the discourse as "an identity having the form of repetition of the self" (Foucault, 2004 p. 16). The author is not necessarily the speaking individual, but the role that gives coherence to the discourse, and in some fields (like the scientific one) attribution is key in reinforcing the claim to truth; it limits the discourse as "an identity having the form of individuality". The discipline is a defined group of objects, methods and propositions considered "true"; to be accepted as part of a discipline, a discourse does not only need to be true, but also to follow some conditions. Restriction systems are more complex procedures that restrict access to the discourse and assure distinction among subjects. The simplest restriction systems are rituals, which define qualities of speakers, gestures and signs. Thematic discourses like the scientific ones use rituals of the word (think to medical diagnostic practices, or the steps of the academic peer review system). Societies of discourse are another example of restriction system, where discourses are protected and circulated only in a restricted space. The meaning given to terms defines the boundaries of disciplines and is used for self-positioning.

securitization from deliberate disease risks would include the establishment of international weapons controls, vaccination campaigns, strengthening of public health regimes, investments in military biodefense research, import/export controls, scientists engagement – in short, a web of prevention.

2.4.4 Choices within the securitization approach

This research could face a dilemma, as it aims at investigating ways to engage different constituencies, and primarily the scientific community into policy issues. This would be nearly impossible given the rigid exclusion procedures of *partage* and discipline, leaving the "security" and the "biology" communities playing with the same terms but different meanings, doomed to never speak the same language. One solution would be to push the boundaries of exclusion to a larger common denominator, including all "security implications from life sciences and biotechnologies", as we said regarding security issues and very compatible with the securitization of international public health.

In this research, securitization theory is used to analyse if and how education has been advanced as a possible security tool to limit the risks of deliberate disease, and how securitization discourses could be drafted in education initiatives specifically targeting students and young scientists as a risk mitigation measure. While not overlooking the importance of the speech act analysis, I accept the proposals of a more socially embedded, historico-political securitization analysis: this means that, besides and beyond analysis of the textual messages of awareness raising I also look at the contexts influencing them and, secondly, not stop at the message but also look at what it has led to, or been accompanied by, impact or change, including using categories and tools of the science of learning as described below.

The embedding into practices and bureaucracies can really be one of the tests of success of the securitization move. These decisions do not mean that I don't try to avoid what I think is a limitation of the judicial analysis of public health securitization, i.e. to consider policy shifts and "new" threats as necessarily exogenous, but the opposite that their historical paths will be more rightfully considered. The historico-political stance to securitization, furthermore, is theoretically consistent with our idea of considering non-state actors as potential securitizing actors, such as civil society including academia, networks of individuals and NGOs, besides state policy makers, and scientists as audience for the securitization messages.[117] Hence the historico-political model of securitization will be applied firstly as an analytical tool and secondly within the generation of educational design and evaluation tools. In the first role, the approach will be utilized on analysing education as security. I will look at what is the securitizing actor, what the referent object, and what the audience. In the second role, I will connect securitization with the methods and models provided by educational science, to design, develop and evaluate the impact of educational messages of security value. In this context I will look at if and how the measures suggested by the contents of the messages were accepted by the audiences and were implemented.

There are, however, considerations to take into account on the use of a securitization approach. Securitization theorists *in primis* sustain that securitization is not always good, and it may actually be undesirable: Waever (1995) already argues that we should aim at desecuritization, to bring back issues in the realm of normal politics and subtract them from the state of emergency. Securitization has also been criticized as possibly silencing underrepresented constituencies and their interests.[118] Regarding the life sciences, biotechnology and public health, securitization opens further challenges: how could (if it should at all) science be overseen to prevent and respond to potential threats; and how could at the same time a securitized sector enjoy the necessary spirit of innovation, freedom and communication levels? These are sensitive points as we indeed aim to not only study but also somehow to create securitization (of collectivities from biosecurity threats, on one side, but also possibly of science from excessive regulation, on the other side) through education. It has also been observed (Charrett, 2009) that a normative dilemma of

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[117] Compatible with the "middle level collectivities" that are the ideal intersubject of securitization moves.

[118] As Hansen (Hansen, 2000) noted, the Copenhagen School's approach to the securitization speech act may leave some constituencies silenced and unprotected, because of the impossibility of voicing threats or because their threatened identity is subsumed by other aspects.

securitization studies is to generate negative securitization processes, replicating dominant modes.[119] This reproduction may especially occur through the confusion between analyst and securitizing actor, a tendency that has been described, among others, by Eriksson (1999). In this sense, securitization seems to have an implied negative meaning. However, we don't think it has necessarily to be that. Our historico-political approach would be compatible with Hansen's guidance of not limiting to the textual epistemological focus for securitization. Also we think securitization may play a restraining or an enabling role, depending on the reasons why it is employed and the normative framework it is inserted in. We think some of the above challenges could indeed be mitigated as we insert the tool of historico-political securitization analysis and creation of education within the web of prevention framework, that would employ education not only as a (restraining) security tool but also as an enabling tool and help in promoting the positive role of scientists and operators to counter deliberate disease.

2.5 Defining and discussing risk

The second key category in the research is that of "risk", both because of the prominent use of the term in the technical arena of biosecurity, biosafety and biorisk management, and because of the aim of the research of measuring the impact of education as a tool to reduce the security risks of deliberate disease. However, "risk" means different things to different people and is a contested concept as, and possibly more, than "security".

2.5.1 Quantitative approaches to risk

One main approach to risk is the realist one, mostly applied in technical fields such as engineering and epidemiological risk management. While recognizing that *decisions* based on risk are not value-free (Bradbury, 1989), this approach sees risks as objective, endogenous and natural, resulting from hazards that pre-exist observation and measurement. According to this approach, "risks are measures of the likelihood of specific hazardous events leading to certain adverse consequences" (Kates and Kasperson, 1983 p. 7029). The idea of risks being influenced

[119] According to critics, the constructivist approach "reproduces the security agenda when it describes how the process of securitization works" (Huysmans, 1995 p. 69).

by, or a measure of, possibility of an adverse event and its consequences, is widely shared in this approach (Bradbury, 1989; Hadden, 1984; Stern et al., 1996; European Commission, 2010b). There are, however, different ways to conceptualize possibility and consequence, including, inter alia, probability and severity (Hadden, 1984), and conditional probability and harm (Hohenemser et al., 1983), or magnitude (Stirling and Mayer, 2000). Certainly risk "involves both uncertainty and some kind of loss or damage" (Kaplan and Garrick, 1981 p. 12); the preference for probability to describe uncertainty is common in the Probabilistic Risk Assessment (PRA) that first developed in the nuclear safety sector[120] and later expanded to wider Quantitative Risk Assessment (QRA). From this approach, the concept that may best fit this research is that of considering risk as a function of likelihood and consequences (Kaplan and Garrick, 1981; Kaplan, 1997; Garrick, 2008; Apostolakis, 2004).

2.5.2Qualitative approaches to risk

Other authors identified problems and limitations with QRA and the realist approach to risk. This includes not capturing influences of human and design errors, or of cultures (Apostolakis, 2004), and considering risks as detached from society and not embedded as social facts (Bradbury, 1989; Lupton, 1999). QRA would necessarily simplify a complex reality and hide uncertainty (or ambiguity) as different and complex parameters are reduced and aggregated (Stirling, 2003; 2006). Also, QRA is accused of depicting humans as strictly utilitarian and rational (Douglas, 1985), and to only focus on the individual as assessor or decider. The realist approach to risk also tends to divide between, and value differently opinions from, "experts" and "lay people", where the former are treated as neutral and bringing the objective and replicable measurement of risk, and the latter as unable to correctly assess it.

On the opposite side of realist approaches to risk, qualitative approaches view risk as socially constructed. The risks we identify, measure and manage do not pre-exist analysis but, on the contrary, are constituted via pre-existing knowledge, values and cultural codes (Caygill, 2000). Three

[120] Modern research on technological risk is regarded as started by Starr's (1969) seminal paper on technology and social benefits.

main social constructionist approaches to risk include the critical structuralist and weak constructionist position of the risk society theorized by Ulrich Beck; the functional structuralist and strong constructionist cultural-symbolic position by Mary Douglas; and the post structuralist position of Foucaultian governamentality (Lupton, 1999). According to Beck (Beck, 1992; Beck et al., 1994; Beck, 2002a; Beck, 2002b; Beck, 2013), hazards are real and natural, but risks are social constructions and their cultural mediations. Beck is not far from the realist point of view in many instances, however, which makes his position a weak constructionist one: risks are a (given, unavoidable and irreversible) outcome[121] of modernization[122], and globalization introduces novel risks[123]. Risk is a "systematic way of dealing with hazards and insecurities induced and introduced by modernization itself" (Beck, 1992 p. 21). There are options – both technical and socially constructed rules – to deal with risk, such as attribution and insurance, but the potentially catastrophic adverse events introduced by modernity break them. In the cultural symbolic position (Douglas, 1985; 1998), on the other hand, risk is a cultural device to identify and maintain boundaries and order, and as such is used by groups

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121 Risks are "manufactured uncertainties" (Giddens, 1991) and an "inescapable indeterminacy" (Wynne, 1983).

122 The "risk society" (Beck, 1992) is the post-industrial one that self-creates, through modernization, new risks that despite being created are less predictable than "classical", external risks. The "constellation in which new knowledge serves to transform unpredictable risks into calculable risks, but in the process it gives rise to new unpredictabilities, forcing us to reflect upon risks" (Beck, 2013 p. 15) is what Beck called "reflexivity of uncertainty". At the same time it is a society that no longer relies on the guidance of traditional or natural laws. According to Giddens (1999), risk society can be traced back to two transformations: the end of nature, as no aspect of life remains untouched by humans; and the end of tradition, where fate does not govern life anymore. Hence, it uses other decision-making tools constructed around risk, such as risk assessment or risk mitigation.

123 With the evolution from "risk society" to "world risk society", Beck introduced a series of innovations specific for the international nature of risk society in the 21st century, including risk as (globalized) anticipated catastrophe and, especially relevant for the security discourse, transnational terrorism as an entire new category of global risk subverting calculations with "intention" in the place of "chance". A type of global risk that is even more peculiar when coupled with cutting-edge technologies that are continuing, as predicted twenty years earlier, to contribute to uncertainty. "Those responsible for well-intentioned research and technological development will in future have to do more than offer public assurances of the social utility and the minimal 'residual risk' of their activity. Instead, in the future the risk assessments of such technological and scientific developments will have to take into account, literally, intention as well as chance, the terrorist threats and the conceivable malicious uses as well as dangerous side effects" (Beck, 2013 p. 14).

and individuals who however are already influenced by "culturally learned assumptions and weightings" (Douglas, 1985 p. 58). While the cultural symbolic position on risk is often described as considering hazards (or risk sources) as socially constructed, coming to existence only when people identify them (Fox, 1998), Douglas actually posits that "real" dangers do exist: "the reality of dangers is not an issue… this argument is not about the reality of dangers, but about how they are politicized" (Douglas, 1992 p. 29). Finally the Foucaultian governamentality position sees risk as a regulatory strategy to manage populations and individuals. Risk strategies are discursive, and they select some or other phenomena as "risky" to impose management on them. Risk is hence unbound from any "external" or "objective" notion of danger.

2.5.3 Bridging quantitative and qualitative approaches to risk

There have been efforts to bridge the realist and constructionist conceptualizations of risk. Scientific behavioural research has, on the one side, demonstrated that the divide between "experts" and "lay people" can be pretentious. Experts are not exempt from bias, while lay people can[124] and actually regularly perform risk assessment, often with richer information than experts (Slovic, 1987), and can themselves become experts, identifying and processing new information (Jasanoff, 1993). On the other side, risk analysis research introduced the concept of risk perception and described factors that would lead to assess risks as "higher" or "lower" (Douglas, 1985; Slovic, 1987; Slovic and Peters, 2006). An integrated, interdisciplinary and pluralist risk management framework[125] would include both technical and social sciences and factors (Royal Society, 2009), indispensable to deal with modern technological and natural hazards (Renn, 1998), and based on the recognition that "scientific risk analysis is unavoidably and inextricably intertwined with subjective framing assumptions, values, trade-offs and expectations of surprise" (Stirling, 1999). It has been advanced that quantitative and qualitative approaches could co-exist and their use would be determined by the amount of uncertainty (increasing uncertainty would increase the influence

[124] Especially, lay people seem to be better able to estimate consequences or risks rather than their likelihood (Jungermann and Slovic, 1993) translated in (Hampel, 2006).

[125] Or of "decision making under uncertainty" (Stirling, 2003)

of cultural factors) (Jasanoff, 1993) or type of risk: risks for which extent of damage and probability are known could be dealt by mainly quantitative risk management strategies; risks with high uncertainty on damage and occurrence would require precautionary measures (Stirling, 2007; 2008); risks with high ambiguity on damage and occurrence will require discursive practices (Klinke and Renn, 2001).[126]

One way to mediate between the realist and constructionist approaches to risk in this research is accepting that they can co-exist in the process of risk assessment. Assessment is the first phase of the basic model for managing biological risks described by the IRGC Risk Governance Framework (Renn, 2006) as well as the WHO (Astuto Gribble et al., 2015). Assessment is followed by Mitigation (i.e., decisions on measures to control the risk) and Performance (measurement of impacts of mitigation measures, review and improvement of the system).[127] Risk assessment includes the identification of hazards and scenarios of adverse events, the characterization of the risks of such events in terms of estimating their likelihood and consequences, and the evaluation or weighting of the risks (Kates and Kasperson, 1983).[128] The idea that risk mitigation decisions are not directly based on description of uncertainties, but rather inform and

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[126] Klinke and Renn (2002) label these three classes Damocles/Cyclops, Puthia/Pandora, and Cassandra/Medusa, respectively. Interestingly, the risk of deliberate disease discussed in this research could fall under each class depending on what "risk scenario" we are considering. A laboratory biosecurity incident may fall under the first one, an advanced gain-of-function experiment with potential biosecurity implications could fall under the second one; and the potential misuse or weaponization of biological agents against the norm prohibiting biological weapons would fall under the third one. Education as a security tool would fall under their risk management category of discursive measures (they mention awareness raising campaigns and codes of conduct), mainly devoted to mitigate the third class of risks in their model. However, it could also be (indirectly) used to mitigate the first two classes of risks as well (for example, by regulating mandatory education, or by teaching scientist the precautionary principle with relation to dual-use).

[127] The Assessment, Mitigation, Performance model is consistent with management systems literature (Labodová, 2004; Moen and Norman, 2006; Brenner, 2007; Du et al., 2008; CEN, 2011; Sokovic et al., 2010; ISO, 2015).

[128] The IRGC Risk Governance Framework groups risk assessment phases in a slightly different way, with a "pre-assessment" phase including framing or risk and definition of the problem; "risk appraisal" corresponding to risk characterization but explicitly including perceptions of stakeholders; and judgement based on tolerability and acceptability that could correspond to risk evaluation. These assessment phases would be followed by "decisions" informing mitigation, and by "communication".

support decision-makers who perform an evaluation (Aven and Zio, 2014; Apostolakis, 2004) based not only on opportunity but largely on values and beliefs (Hansson and Aven, 2014), is widely accepted. However, I accept the position that evaluation should be an integral part of risk assessment and not an intermediate step between assessment and mitigation. This does not only include "the so-called objective activities of risk identification" and characterization, but that they "need to be integrated with, rather than separated from, the subjective process of evaluation" (Bradbury, 1989 p. 381)[129]. The process for risk identification and characterization phases derives from the model by Kaplan and Garrick (Kaplan and Garrick, 1981; Kaplan, 1997; Garrick, 2008) that is based on triplets of "fundamental questions": what could go wrong? How likely is it that that will happen? If it does happen, what are the consequences? However, even the "objectivity" of risk identification and characterization are questionable: would different assessors identify the same "wrongs"? Are likelihood and consequence going to be equal in different analyses?[130] The authors warn that risk is relative "to the observer" and "it is a subjective thing – it depends upon who is looking" (Kaplan and Garrick, 1981 p. 17). Furthermore, risk is relative to other risks[131], and it cannot be conceived alone or in absolute terms (it makes little sense to say something is "high risk" - if we do, we are implying a comparison to other risks, with some explicit or implicit scale).[132]

There are components of both realism/objectivity and constructionism/subjectivity in all approaches to risk, from the identification of "real" hazards or dangers, to the concept of relative risk, to the components of risk assessment and the motivations for risk management

[129] Bradbury uses "estimation" in lieu of characterization.

[130] As Slovic (1986 p. 404) notes, "people are at the mercy of how information is presented to them", or take different choices if they are presented with, for example, absolute or relative characterization data.

[131] "Given two meaningful statements (or propositions or events), it makes sense to say that one is more (less, equally) likely than the other. That is, we accept as an axiom the comparability of uncertainty" (Kaplan and Garrick, 1981 p. 17).

[132] If we said that one scenario is "low risk", without any comparison, it would be meaningless. We could, for example, introduce a second scenario that is less likely and has less harmful consequences, and by comparison the first scenario would be "higher risk". Risk is always "higher" or "lower" than other risks: either explicitly or implicitly if using a pre-defined scale.

decisions. As studies confirmed (Marris et al., 1998), the inclusion of constructivist or even relativist assessment into objective or quantitative models doesn't preclude that risks can be categorized and ranked according to a number of factors. Some observe that risk management literature uses a "subjectivist interpretation within a realist paradigm" (Bradbury, 1989). Given the considerations on risk assessment components, this research would rather try to answer questions posed with a "realist" approach (such as how to manage security risks, and how to measure the impact of education as a security risks mitigation tool) within a weak constructionist epistemological position. We recognize that some dangers exist in themselves, but also that some are constructed, or may be assessed differently in different contexts. We accept that risk assessment should integrate risk identification, characterization and evaluation.[133] This stance is consistent with both the securitization approach used to analyse the movement of education into the security toolbox, as well as Ulrich Beck's world risk society position.[134] Beck recognizes that separating between "perceived risk" and "risk" (whatever the latter may really be) is difficult and unnecessary: risk is really the (staged) anticipation of a catastrophe, that "obliges us to take preventive action" (Beck, 2013 p. 11).

2.5.4 How to assess risk

Following the outlined approach to risk, it remains to discuss how to answer the three questions. Answering "what could go wrong?", i.e. risk identification, is really an inventive part[135] to find the possible undesirable scenarios (Kaplan, 1997). The first step is identifying the possible hazard(s)[136] and threats[137] in the activities and subsequently the adverse

[133] Something that, although from a more quantitative point of view, has been advanced by managerial applications of the quantitative definition of risk. Wall (2011) for example adds to the Kaplan and Garrick definition the fourth dimension of decision-maker preferences.

[134] Which is itself compatible with the historico-political securitization approach, as global risks (including transnational terrorism) are constructed through struggles of competing definitions.

[135] Kaplan (1997), for example, suggests using TRIZ to project trajectories from a Scenario 0 situation.

[136] The hazard is the source of harm through an adverse event, while risks are a measurement of the conditional probability of experiencing harm (Hohenemser et al., 1983).

[137] Threats are people with the intention to cause harm, additional sources of risks for security risks with respect to safety risks.

events that they may cause in risk scenarios (Haimes et al., 2002). The second and third questions constitute the risk characterization step within risk assessment. It implies collecting and analysing all factors that may influence likelihood and/or consequences of the identified risk(s). Proposed structured methods to analysing factors in risk assessment include criteria filtering and ranking and Multi-Criteria Decision Analysis (MCDA), that characterizes, relatively, various risks factors using qualitative definitions; these methods are used to inform decisions in situations of limited and evolving knowledge from multiple sources (Leung et al., 2004; Linkov et al., 2007; Caskey et al., 2010). MDCA methods are based on weighted sum algorithms of multiple factors evaluated against each other (Caskey et al., 2010).[138]

Factors may include characteristics of the hazard and of the situation, including where and when the scenario is taking place, who is involved and what are the available mitigation measures. The characterization of security risks adds the consideration of threats as intelligent adversaries, including their adaptation to the defender's moves (Cox, 2008; Golany et al., 2009; Brashear and Jones, 2010; Parnell et al., 2010 p. 1758; Aven and Zio, 2014) based on the information available to them (Brown and Cox Jr., 2011), and to the system's vulnerabilities to intentional attacks (Depoy et al., 2005; Sandia National Laboratories, 2014b).[139] Criteria to characterize risk may include probability of occurrence, extent of damage, incertitude, ubiquity, persistency, reversibility, delay effect and potential of mobilization (Hohenemser et al., 1983; Klinke and Renn, 2001). Likelihood can be measured depending on the type of uncertainty and available data (Aven, 2011); consequences may be represented, for example, with number of lives lost or cost for repair. Uncertainty can be embedded in the

[138] Caskey et al (2010), for example, compare each factor pair-wise attributing weight factors from 1 (equal importance) to 9 (significantly more important).

[139] The US National Research Council (National Research Council, 2008), among others, has criticized the US DHS' Risk Analysis Methods reliance on PRA, on the basis that it does not take into sufficient account the nature of intelligent adversaries. Hence for including factors of threats as intelligent adversaries, a dynamic risk characterization model (that employs, for example, probability, event and decision trees; game theory; influence diagrams; or Bayesian network analysis) may be more effective than static PRA characterization (Ezell et al., 2010). Consider also how terrorist actors may not follow rational planning and adaptation (Cox, 2008).

representation through exceeding probability curves, indicating the probability that certain levels of losses will be exceeded (Kunreuther, 2002). We assume that risks can be described relative to each other, to other risks, or over time.[140] A number of characterized risk scenarios can hence be related to each other and plotted on a graph where on one axis lies relative likelihood and on the other axis is relative consequence.[141] Our goal however is not measuring the risks (or better, as we shall see, various risk scenarios) of deliberate disease, but rather to discuss the impact of education on it. Instead of developing a(nother) characterization of the risks of deliberate disease, we are interested in identifying what are the factors affecting likelihood and consequences of the risks of deliberate disease that may be influenced by education.

[140] It has been argued on the other hand that also characterization, besides evaluation as discussed later, can not allow comparisons: "the relative priority attached to the different dimensions of risk is intrinsically a matter of subjective value judgement" (Stirling, 1999 p. 10). While it is true that with high degrees of uncertainty to incorporate some risks become incommensurable, this is not necessarily the case of any risk; and decoupling characterization and evaluation allows relative characterization and subjective evaluation to be both discussed addressing the limits of "narrow notions of risk" pointed out by Stirling (1999; 2006).

[141] This is also used with quantitative measurement of risk. In that case, logarithmic scales are often used, that are "practical for cases where successive occurrences range over a factor of 10 or more in magnitude and where estimated errors easily differ by the same amount. Logarithmic scales may also mark human perception better than linear scales, as seen by the success of the decibel scale […] and the Richter scale" (Hohenemser et al., 1983 p. 280). However, especially for security risk scenarios in which certain information on intentioned threats are limited, relative qualitative scales of consequence and likelihood are preferred (Leung et al., 2004 p. 976). Scales may also be defined for each element between "absence" and "highest possible value", or "best case" and "worst case" (Caskey et al., 2010).

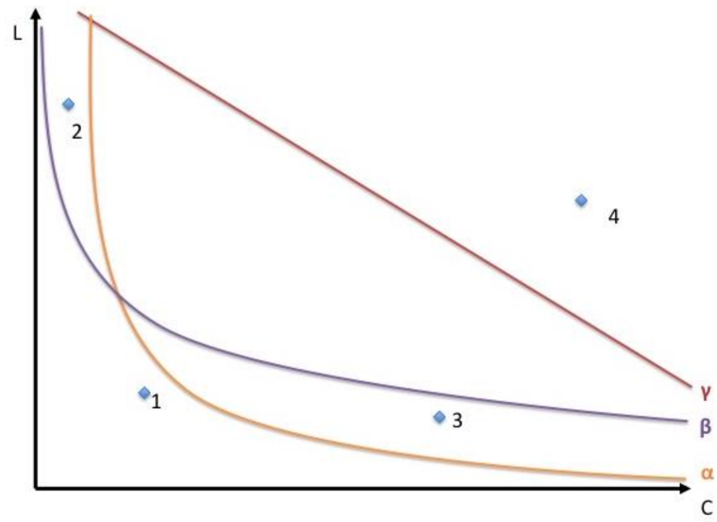

Figure 1 - Characterization of four risk scenarios and their different evaluations

Regarding risk evaluation, literature discusses what would be "acceptable"[142] risk and what are acceptability criteria. Discrete thresholds of risk acceptability have been proposed[143], however we will follow the thesis that evaluation is the (most) subjective feature of risk assessment, and that acceptable risk is *that that is accepted*.[144] Criteria for acceptability could include "absolute" terms, such as number of lives,[145] lifetime spent versus gained (Lind, 2002), dollars of potential damage, degree of certainty; or ratios between risk and benefit.[146] Evaluation could also be influenced by feelings, sensitivity (Slovic and Peters, 2006), closeness, controllability, trust (Hampel, 2006), voluntarity, available resources (Hattis and Minkowitz, 1996), spectacularity of accidents (Vrjling et al., 1995),

[142] It has been proposed (Kasperson et al., 1988) that "tolerable" may be a better term than "acceptable", since one doesn't really accept an adverse event, but rather lives with it. Despite the sense of the proposition, we follow the use of "acceptable" that is more widespread in literature.

[143] "Acceptability of risk is roughly proportional to the third power of the benefits for that activity and the public will accept risks from voluntary activities that are roughly 1000 times as great as it would tolerate from involuntary hazards that provide the same benefits"(Starr, 1969).

[144] As an illustration of the relation between the relative but objective process of characterization and the subjective one of evaluation, see reports by Hohenemser (1983) and Tversky and Kahneman (1975) where risk assessments by lay people were highly correlated with scores derived from the scientific literature, but deviated with strong biases towards risks characterized highest and lowest.

[145] For example, the Dutch Ministry of Housing, Spatial Planning and the Environment defines as acceptable the death of 10 or more "people in case of failure of a LPG station with a probability of 10^{-5} per year" (Vrjling et al., 1995 p. 249). Thresholds of acceptable risk can be expressed in absolute or relative (as low as reasonably possible, or ALARP, model) terms, each denoting policy and possibly ethical choices (Aven, 2007).

[146] People may be as more willing to accept a risk, as higher is the benefit from that activity.

regulatory requirements, value of the work, public perception (Caskey et al., 2010), and how results of characterization are presented[147] (Stone et al., 1994). People can be likelihood- or consequence-averse, and particularly tend to neglect likelihood in case of consequences generating strong feelings (Loewenstein et al., 2001).

As exemplified in the figure above, in a graph where different characterized relative risk scenarios have been plotted (1-4), evaluation can be depicted as lines or curves connecting the points where one's evaluation is the same and would pass from "acceptable" to "unacceptable", hence they are referred to as isoquants. All characterized risk scenarios below an acceptability isoquant would be "acceptable" (or, equally, all characterized risk scenario below a "low risk" isoquant would be evaluated as low risk). Different evaluation isoquants would depict different evaluations, with lower isoquants only accepting lower risks than higher isoquants. Isoquants can have a variety of shapes, for example be flatter on the likelihood or consequence axes for people that are especially reluctant to accept risks relatively more likely or with relatively higher consequences, respectively. Isoquants would have a negative coefficient, reflecting a substitution rate between acceptable likelihood and acceptable consequence. In this sense, they reflect the preferences payoff functions advanced by the managerial approach (Wall, 2011). In the figure, assessor α is more consequence averse in their evaluation than assessor β, who is more likelihood averse. The former would accept risk scenarios 1 and 2, while the latter would accept risk scenarios 1 and 3. Assessor γ would have higher risk acceptability in general, and the same relative value of likelihood and consequence; they would accept risk scenarios 1, 2 and 3. No assessor would evaluate risk scenario 4 as acceptable.[148]

Though it's important to have the determinants of risk evaluation clear, this research won't suggest the acceptability of specific deliberate disease risks. Rather, we will focus on the determination of any impact from the

[147] It has also been observed that knowing of the risk may make it more likely, hence influencing characterization: "the likelihood that a single event will occur increases when this event is cognitively available" (Hampel, 2006 p. 8).

[148] The evaluation of the same characterized risk can also change due to a new accident or other factors (Vrjling et al., 1995).

use of education as a tool to mitigate the risks of deliberate disease on factors influencing the characterization of relative risks.

2.6 Education on security in science: insights from the science of learning

The third category and research tool used in this work is that of education. A research that looks at the role of education to advance security objectives – in particular that of reducing deliberate disease risks - has to combine educational theory with security studies. Educational science developed especially since the 1960s and based on insights about how people learn as well as empirical results of instruction. As the US National Research Council and others noted, the impact of the science of learning on contemporary education is emerging regarding both effective delivery methods and contents of education that increasingly look at interdisciplinarity (National Research Council, 2000; Salas and Cannon-Bowers, 2001; National Research Council, 2010; Haak et al., 2011). This includes attention to the role and responsibilities of scientists in the society (National Research Council, 2003a). Specific insights from educational science that will be applied in this research will be models of instructional design; evaluation methods to assess impact of education on both learning and risk; and learner-centred instruction methods as effective delivery of education. It's worth noting though that this research does not focus on education per se, but rather we utilize theories and instruments from the science of learning as tools within a security risks discourse.

2.6.1Instructional design and the ADDIE model

Instructional systems design or development (ISD),[149] is both a discipline and a professional field concerned with creating instruction. It has been noted (Ely, 1992; Bassi and Van Buren, 1999; National Research Council, 2003a) that the major trend in education technology is to base education on instructional design and development principles. As its name suggests, systems have an important part in ISD. As Andrews and Goodson (1980) note, the ISD process is systematic, as it is a problem-solving approach

[149] The concept is sometimes, and was originally, referred as Instructional Systems Development. I prefer to use Instructional Systems Design not only for consistency with prevalent recent literature but also, as we shall see, because Design is the core concept and predominant phase of creating instruction.

proposing a defined cycle that includes input, output and feedback phases.[150] At the same time ISD is also systemic as each of its components impacts directly or indirectly the others. ISD is explicitly based on systems theory, and in particular on the work by von Bertanlanffy (Hodell, 2011). According to Banathy (1987), a systems approach addresses "highly complex, large scale problems, it is non-linear, synthesis oriented and holistic, and employs strategies that represent a set of interrelated concepts and principles". Other roots of ISD are, in the social sciences, behaviourism (Hodell, 2011 p. 13) and constructivism, and more specifically in the science of learning, the work of Benjamin Bloom on the taxonomy of cognitive thought (Bloom, 1956).[151] The taxonomy is frequently used in the design of scientific and medical education (Patel et al., 2009), and it describes how learning occurs in subsequent stages from basic assimilation to more advanced elaboration. The original taxonomy used six categories of "cognitive domains": knowledge, comprehension, application, analysis, synthesis and evaluation. Each domain was a prerequisite for the student to achieve the next one. Krathwohl (2002) proposed a revised version of the taxonomy with the following cognitive domains: remember; understand; apply; analyse; evaluate; and create.[152] He furthermore proposed singling out "knowledge" as a cognitive domain and breaking it up in three dimensions: factual, conceptual and procedural. I will use a similar approach in that I will adopt "cognitive domains" to describe three dimensions of theoretical knowledge ("know"), attitude ("feel") and practical skills ("do"). These domains as I intend them are not ranked in terms of cognitive challenge, as there can be more or less advanced capacities both in the theoretical and practical fields. Rather, and much in line with the revised taxonomy above, they would intersect

[150] Edmonds et al (1994) interpose a "process" phase between input and output of the systematic ISD approach.

[151] Several of the models from the science of learning that we introduce, such as ISD but also Gagné's events of instruction and the Bloom's taxonomy, are influenced by a behaviouralist approach. This is not an absolute choice however, as some tools that will be introduced later such as Kolb's contribution on learning styles claim to be "experiential" rather than behavioural.

[152] Krathwohl (2002) explains, firstly, that it is better to use verbs instead of nouns to describe learning actions, and to do it consistently; that the original knowledge domain is better described by the remember category to avoid confusion with the introduced different plans of knowledge; and that synthesis would change place with evaluation and be renamed "create".

“learning levels” (that are really levels, as they require incremental cognitive capacities) as per revised Bloom’s categories. Furthermore, I will keep “evaluate” as the highest learning level, as I think it stresses the required advanced component of critical thinking from the student, while “create” may well be present in other learning levels.

The earliest among applications on a variety of topics and disciplines, ISD has also been used to create teaching on safety and security related to biotechnology and the life sciences. Delarosa et al. for example started with the identification of job tasks and desired competencies for laboratorians (Delarosa et al., 2011). Within the wide rubric of ISD, a variety of models have been proposed and identified. As Andrews and Goodson (1980) noted, it is not always clear if models have been empirically validated, and how to choose the most appropriate one. However, a number of comparative studies on ISD models (Andrews and Goodson, 1980; Edmonds et al., 1994; Gustafson and Branch, 2002) identified their recurring components, such as: formulation of observable goals and sub-goals; tests; characterization of audience, instructor, and constraints; type of instruction; size and context of instruction; delivery methods; development of educational materials; results assessment, feedback and revision. Among these components, the most defining one for the ISD approach is stating specific educational objectives or desirable learning outcomes. These are defined as “specific, measurable learning goals, i.e. what students will know, understand and be able to do” (Handelsman et al., 2007 p. 20). Education and professional development (training) based on desired competencies has also become particularly popular in life science and health education (Koo and Miner, 2010). However, all major components of ISD could be reduced to a higher-level model as the one that we use in this research. The ISD model described by the American Association for Training Development (ASTD) (Hodell, 2011) is one of the most structured and refined applications of what has been informally termed the ADDIE model for ISD, and the one that is mostly applied in this research. ADDIE comes from the initials of the five main phases of this highly flexible instructional design model: Analysis, Design, Development, Implementation and Evaluation. ADDIE is not a formalized model in itself, nor is it clear who firstly described the process using this label (Molenda, 2003). The early instructional design model that later developed into the ASTD approach is the Interservice Procedures for Instructional Systems Development (IPISD) designed for the United States Army by Branson et al. (1977).[153] Nonetheless, as emerges from the classifications of instructional design models, the ADDIE approach includes all the components advanced by other instructional design scholars (Bonner, 1982; McCombs, 1986; Gustafson and Branch, 2002).[154] These components can be grouped under the analysis, design, development, implementation and evaluation categories.[155]

2.6.2 Four levels of impact of education

Methods to evaluate education in structured training and its impact is regarded as an important aspect by educational science contributions (National Research Council, 2003b; Bober and Bartlett, 2004). Kirkpatrick's (1976; 1979; 1996; 2006; Kirkpatrick and Kirkpatrick, 2007) model for evaluating training programs will be leveraged in this research to evaluate education regarding both learning and security objectives, according to specific indicators and metrics. Kirkpatrick's model has a long history of application in training programmes, traditionally and most popularly in business organizations (Bates, 2004) and project management (Steensma and Groeneveld, 2010; Buganza et al., 2013). However, the model has also been used in other instructional contexts (Arthur Jr et al., 2003) as well as applied in higher education (Praslova, 2010). The model helped to highlight the importance of design for evaluating training programmes (Steensma and Groeneveld, 2010), and in general to base evaluation of education on learning objectives.

[153] That model was extensively applied in the US military before being applied in other sectors. That IPISD model (Branson et al., 1977; Branson, 1978) used the same phases summarized in ADDIE, though Evaluation was labelled "Control".

[154] As Gustafson and Branch (2002) note, the IPISD model, at the root of the ADDIE model, can be classified as systems-oriented in contrast to more classroom-oriented and product-oriented instructional design models.

[155] I will use the capitalized words to refer to the structured five phases of the ADDIE model we use, and lowercase initials when I refer more in general to the categories or the actions of analysis, design, development, implementation and evaluation.

The model describes objectives of educational programs in four levels. The first Level is the reaction, or how participants (students) are satisfied about the education. The second Level is properly learning, or what knowledge, skills, and attitudes have changed as a result of education, i.e. if learning objectives have actually been achieved. Level three looks at if and how what is learned is transferred into usual practice; instructional designers also label it "behavioural change". Finally, Level four looks at the broader results of education, and if and what change has occurred because of the education in terms of organizational change. The distinction among different areas or levels of evaluation for education is common to other training evaluation models: Kraiger et al (1993) for example distinguish between "training effectiveness" and "training evaluation", with the former being more general and looking at the system perspective, and Praslova (2010) distinguishes between "internal" and "external" evaluation.[156] Criticisms of Kirkpatrick's model of evaluation of education and training contend that it is incomplete and does not consider factors such as culture, organizational goals and adequacy of resources (Bates, 2004); and that it assumes causal relations while some analysis suggest a lack of correlation between the levels (Alliger et al., 1997). However, studies have also found indications of strong linkages especially between level one and the following levels (Kraiger et al., 1993), though less among the higher three levels (Dixon, 1990; Alliger et al., 1997; Morgan and Casper, 2000; Arthur Jr et al., 2003). Though relationships between levels two, three and four have been also reported (Buganza et al., 2013), the modesty suggested by some studies could be due to lack of opportunities to investigate the impact (Arthur Jr et al., 2003) and hence a problem of integration of the four levels model into instructional design, rather than of the evaluation model itself (Praslova, 2010). In this sense, the biggest challenge is to design appropriate indicators and metrics to populate the four levels model. In particular, the stress on level four is noteworthy as it focuses on evaluating ultimate results of training, as stressed early by science of learning literature (Likert, 1958). Level four

[156] These distinctions could be paralleled to Kirkpatrick's first and second level, on the one hand, and third and fourth levels, on the other hand. In this sense, we prefer Kirkpatrick's model also because it provides a higher "resolution" of analysis.

goals are determined by designers and reflect some worthy results, that in some contexts can be related to production, financial assets, or quality (Kirkpatrick and Kirkpatrick, 2007). In our case, they will be related to lowering the risks of deliberate disease. Level four goals in this model have also been discussed before in relation to higher education, as reflecting the goals that "accreditors, governments and workforce representatives" expect will be served through the competences and skills that higher education institutions will prepare students with, before they enter the labour market. In general, Kirkpatrick's typology "has served as a good foundation for training evaluation for many decades" (Salas and Cannon-Bowers, 2001 p. 487). This model of evaluation is also compatible with ISD and the ADDIE model, as it stresses the importance of setting desired outcomes upfront and of proceeding backward to development and design.

2.6.3 Learner-centred as effective education

Literature on education about security issues in the life sciences explicitly mentioned that the particular nature and objectives of these efforts would be best delivered by the use of modern teaching methods. The US National Research Council (National Research Council, 2010) advanced that the complex, subjective and multidisciplinary dimensions of the subject require educational methods that promote critical thinking and application. Successive initiatives built on this consideration, as development of educational content on responsible conduct and security risks was coupled with development of active learning techniques (National Research Council, 2013). The recognition of modern teaching techniques as effective to deliver education is, however, not exclusive to health and security issues nor the life sciences. Over the last century, understanding of how people learn suggested pedagogies that leverage the natural ways of learning for improved and lasting effects. Though often connected with practical activities and based on the experiential learning theory (Kolb, 1984), "active learning" does not necessarily involve movement. Its characteristic is being learner-centred rather than instructor-centred as traditional lecturing: the learner is endorsed of not only receiving information but also of producing it, collaborating in their own learning process and according to their learning style (Gardner, 2011).

Evidence on active learning pedagogies, such as problem–based and learner-centred approaches, supports that it leads to improved training results in terms of the first level of training impact, i.e. satisfaction of students (Weimer, 2002), and of the second level, i.e. learning outcomes, versus traditional lecturing in science, engineering and mathematics (Scott Freeman et al., 2014) and undergraduate biology (Armbruster et al., 2009). Clearly learner-centred instruction has positive impact on training outcomes (Ruiz-Primo et al., 2011), particularly on problem-solving and higher order learning (Prince, 2004; Haak et al., 2011; Michael, 2006). The US National Academy of Sciences collected results from active learning literature. In particular, a report underlined the impact of active learning on students' abilities to transfer knowledge and skills to new situations, and that learner-centred instruction should be applied in different adult education contexts, levels and disciplines (National Research Council, 2000). Active learning is also more effective in achieve learning objectives in cognitive domains of skills and attitudes, while traditional methods focus only on the knowledge cognitive domain and leave the development, in the other two areas, largely to the learner's initiative (Colliver, 2000; Michael, 2006; Prince, 2004). With regard to teaching of scientists, it has been noted (Johnson, 2012) how active learning formats may be particularly useful to teach philosophy and ethics to students of life sciences and biotechnology who do not have the skills for philosophy, do not know the expectations of philosophy, or are hostile to philosophy.[157] There are also accounts of less clear evidence of the effects of active learning and/or their benefits are worth extra investment, as Colliver (2000) analysed with regard to problem-based learning curricula, or as Halloun and Hestenes (1985) suggested that while innovations had a positive effect on learning, it was variable and not clearly measured. However, more recent and comprehensive meta-analyses seem to reinforce the case for positive and worthwhile effects of learner-centred instruction on academic performance,

[157] The role-playing active learning format, for example, may be more impactful than a typical learning format of the humanities like essay writing. Johnson's (2012) experience suggests that the context of C.P. Snow's (2012) "two cultures" between sciences and humanities would still be valid, at least for education. In this research I present and discuss different experiences of mixing both contents and formats of science and humanities education.

versus traditional lecturing especially in the sciences (Freeman et al., 2014).

This research employed learner-centred instruction principles in the design, development and implementation of education, compatibly with the freedom in design possible in the different contexts where the research was carried out. Besides the design principles introduced above, models applied in the Development and Implementation phases of the ADDIE cycle include the scheme of learning events proposed by Robert Gagné and Leslie Briggs (Gagné and Rohwer, 1969; Gagné et al., 1992), instruction agendas for learner-centred instruction (Jensen, 2005; National Research Council, 2000), consideration of learning elements or principles (Thorndike, 1932), and learning activities according to Kolb's experiential learning model (Kolb, 1971; 1973; 1976; 1984; Kolb et al., 2001).[158] Characteristics of the experiential learning model include the interaction between theory and practice, and the consideration of different learning styles of students. Kolb posits that "learning is a process whereby concepts are derived from, and continuously modified by, experience" (Kolb, 1984 p. 38).

It was not possible to apply active learning designs in part, or completely, in all contexts, not least because "there are similarities and differences in education philosophies, approaches to teaching and learning, facilities, and resources among nations" (National Research Council, 2013 p. 5). The experiences with different educational techniques and methods, though not always optimal, provided, however, the opportunity to discuss variances among educational methods. The approaches leveraged from educational science are also connected with the general weak social constructionist approach of the research. On the one hand the above discussion suggested that social constructionism has an influence in pedagogy and the science of learning;[159] on the other hand we recognize

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[158] Experiential learning is explicitly based on the cognitive psychology work by Lewin, Dewey and Piaget and, as hinted before, instances from behavioural traditions of Hull and Skinner, among others.

[159] At the least with the general recognition that education and learning are socially situated, if not dependent. A social constructionist influence on the conceptualization of learning includes

that instructional design takes place and has to consider cultural and socio-economic contexts.

2.7 Education in the web of prevention

The web of prevention is the end state in which this research would place education of scientists as a potential tool to prevent the risks of deliberate disease. The concept of the web advances that, in order to ensure security, a range of measures, stakeholders, and disciplines, has to be involved. It opposes views that see security in the life sciences as field-limited: laboratory safety, national legislation, ethical deliberations, and/or international treaties. The concept of the web of prevention for the life sciences originated in the 1990s (Feakes et al., 2007), and is based on the idea that no single solution can exist to assure security related to this scientific and societal aspect. Pearson described a "web of deterrence" for biological weapons that should comprise comprehensive, verifiable, global arms control; export control and monitoring; effective defensive and protective measures; and effective national and international responses to acquisition and/or use (Pearson, 1993). Over the years, the concept has been enlarged to include measures that are not only in the sphere of governmental activities but that also include professional associations, editors, academia and the scientific community in general (Feakes et al., 2007). The web of prevention envisaged by the International Committee of the Red Cross is a "broad and integrative approach that should be taken by all those concerned to minimize the risk" (ICRC, 2003).

2.8 Conclusions

This Chapter presented the theoretical framework to study education as a security tool to prevent the risks of deliberate disease. Three main conceptual areas and categories interplay in this research: security, risk, and education; all within a social constructionist approach. Securitization and risk assessment will be used in order to analyse attempts to advance education of scientists (particularly focusing as pre-service education) as a

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considering that it happens in historical, socio-economical and cultural contexts that education has to take into account. Furthermore, learner-centred approaches are compatible with constructionist views in believing that learners have an active role in learning and in shaping their competence, while the teacher's role if more similar to a facilitator than an instructor (Lebow, 1993; Prawat and Floden, 1994; Phillips, 2000).

tool to manage the risks of deliberate disease. The concept of risk is leveraged to identify and characterize risk scenarios of deliberate disease and understand if education interventions may impact factors influencing likelihood and consequence, as well as on how risk assessors evaluate risk. Educational models are applied to design instructional systems for scientists during their formative period, as well as to assess their impacts on learning, behaviour and risk. Three main models from educational science are leveraged: ISD, the Kirkpatrick model of four levels of impact, and techniques responding to the principles of "learner-centred" teaching. The framework leverages theoretical bases from social, security and educational studies, and critically combines components of securitization, discourse analysis, risk assessment, science of education, and the web of prevention. Even with the mobilization of varied components, the research relies on a common denominator of macro (weak) constructionist approach to security, risk, and education. For what regards the scope of such a research, Rappert (2007a) discussed what the contribution could be of a social analysis on the concerns of biological research with the potential to be misapplied to intentionally cause harm. One option from a more "objectivist" point of view would be that to propose "definitive assessments" (Rappert, 2007a p. 50) on risks. Another approach, a "constructivist" one, would treat disagreement as a "phenomenon for examination itself" and devote attention to how claims are made and, actually, constructed. This lens, very compatible to our approach, is just a prerequisite choice to determine the type of contribution the research can offer. Rappert mentions among possible contributions an understanding of the different discourses applied by actors to the issue; an analysis of the interests of those actors and how discourses may serve their goals; and/or an analysis of the argumentative resources employed by actors. The ultimate intended contribution of this research is to understand how claims of education as a security tool to mitigate the risk of deliberate disease have been made, if education can actually have an impact on that risk, and, if yes, how can it be effective.

Regarding ontological and epistemological stances, my approach remains with constructionism, and as such not necessarily endogenous as described by the judicial-legalist approach to securitization and most of the technical risk management literature. I accept the deepening and broadening of security, and I consider a natural consequence to place the topic of this research as a security tool within the web of prevention of deliberate disease. I will apply securitization analysis to speech acts and discourses, as prescribed by the Copenhagen School, however expanding its methodology. My analysis, accepting the historico-political model of securitization, looks at: before the speech act, arguments of the securitization discourse; during the speech act, context and audience(s); and after the speech act, success of the discourse in becoming hegemonic grammar, and actual embedding of what urged by the discourse in institutional and bureaucratic practices. The tool of historico-political securitization, and the insertion of educational messages in the web of prevention framework, would be employed, besides the epistemological reasons, also to mitigate the potential implications of silencing constituencies or reproducing negative securitization practices. Building from the deepening of security, we will consider as acceptable securitizing actors not only states (both at the national level and as international governmental organizations), but also components of the civil society such as national and international NGOs, academia, and scientific organizations. The discussion on risk will include identification of possible risk scenarios of deliberate disease, and of factors that would influence those risks characterization and evaluation, within risk assessment, to then argue what factors have the potential to be influenced by education. While this approach to risk may seem accepting entirely a quantitative risk analysis approach, I have argued as those tools can be actually unveiled as considering risk as always relative in characterization, and influenced by perception, identities and several other constructed factors in subjective evaluation. My approach is also integrated with the concepts of the macro (weak) constructionist vision of risk. This framework will allow the research to discuss the questions on how education was constructed as a potential security tool to deal with deliberate disease risks; if and how could education influence deliberate disease risks; and what could be effective options for education to mitigate deliberate disease risks.

3. The Risks of Deliberate Disease

This Chapter will discuss an assessment of the risks of deliberate disease, and identify where and how education could potentially lower risks. Following the approach described in the previous Chapter, I will apply it to deliberate disease risks firstly going through risk identification, describing what are the dimensions of deliberate disease risks, and what specific risk scenarios we focus on. Secondly I will discuss risk characterization, identifying several factors influencing likelihood and consequences of deliberate disease risks, and discussing if and how education may influence them. Thirdly I discuss what factors impact evaluation of those risks.[160]

3.1 The possibilities of deliberate disease

Risks related to the life sciences and technologies may include natural disease outbreaks, loss of biological diversity, accidental release of pathogens, other harmful biological materials or toxins, and biosecurity risks. Biosecurity risks regard events where a threat has a malicious intention "focused upon an item of value or asset" (Caskey and Sevilla-Reys, 2015 p. 46).[161] Deliberate disease risks refer to biosecurity risks in which the intention is to acquire and/or use the asset to cause disease. In this paragraph I will discuss the history and dimensions of deliberate disease risks.

Science and technology raising security concerns for their potential to enable destructive applications is neither a new nor a specific issue of

[160] This is consistent with other studies applying the framework to biological and other risks (WHO, 2004; Caskey et al., 2010; Gormley et al., 2011; CEN, 2011; Caskey and Sevilla-Reys, 2015). The first phase corresponds to the first question in the Kaplan & Garrick model, "what could go wrong?" and integrates identification of hazards and risk scenarios; while the second ("how likely it is that it will happen?") and third ("if it does happen, what are the consequences?") questions correspond to risk characterization.

[161] Examples of biosecurity risks scenarios could include a farmer intent on infecting a competitor's flock of birds; an employee upset with someone and making them sick; a criminal with the intention of stealing and selling assets; an adversary intent on damaging a research project; a competitor intent on producing a competitive vaccine; someone intent on sabotaging an institution's reputation (Caskey and Sevilla-Reys, 2015 p. 55); the non-peaceful application of biology in states' military programs; and the misuse of results of peaceful research for non-peaceful uses.

biology.[162] Within CBRN weapons, including WMD, the potential intentional application related to biology is devised in the deliberate inducement and/or spreading of disease, and the means to achieve this in biological weapons (BW). BW share with chemical, nuclear and radiological weapons a label of unconventionality, international prohibition regimes, as well as a commonly perceived stigma. However, BW are peculiar under a number of aspects. Under the technical aspects, first, most agents involved in traditional BW are naturally occurring and more accessible than chemical precursors, fissile or radioactive material. Second, they are self-replicating, and small quantities may lead to extensive cultures difficult to detect and account for. Third, while the technology to produce nuclear and chemical weapons has remained substantially the same in the last decades, advancements in life sciences and biotechnology are making potentially dangerous agents increasingly easy to obtain, manipulate and even create; are reducing the resources, technology and knowledge needed to do so in many countries, facilities, public or private sectors; and with other converging and emerging technologies are opening entirely new challenges. Fourth, BW are almost entirely based on dual-use materials, equipment and knowledge with much more blurred lines between hostile and peaceful applications than in the case of nuclear technology. This makes it challenging to verify hostile applications, while impeding excessive restrictions on scientific advancements that bring enormous benefits in the fields of public health,

[162] Historical examples date back to hesitations of Leonardo da Vinci on potential military application of his inventions (Bezuindenhout and Rappert, 2012), or to considerations on mechanical arts by Francis Bacon, who stated: “certainly human life is much indebted to them, for very many things which concern both the furniture of religion and the ornament of state and the culture of life in general, are drawn from their store. And yet out of the same fountain come instruments of lust, and also instruments of death. For (not to speak of the arts of procures) the most exquisite poisons, also guns, and such like engines of destruction, are the fruits of mechanical invention” (Bacon, 1858 p. 753). In the twentieth century, an example of discussions about potential destructive applications of science and technology regarded nuclear energy. Contemporary examples may include nanotechnology, cybertechnology, and 3D printed firearms. A report of the US National Academies assessing ethical, legal and societal issues (including aspects of security issues) of Emerging and Readily Available (ERA) technologies chose to evaluate three “foundational technologies” and four applications domains: information technology, synthetic biology, and neuroscience; and robotics, prosthetics and human enhancement, cyber weapons, and nonlethal weapons, respectively (National Research Council, 2014).

food security, and energy, inter alia. BW are also different from other WMD under military aspects as they can constitute force multipliers for conventional military operations as well as being poorly suited to serve as strategic deterrence (Koblentz, 2009). Under political aspects, BW are different to other WMD as they "do not present a traditional, state-centric 'disarmament' or 'arms control' security problem, because they are banned and should not exist" (McLeish and Nightingale, 2007), there is no discrimination between biological weapons and non-biological weapons states like for the nuclear nonproliferation regime, and no oversight on destruction such as in the chemical disarmament regime (Littlewood, 2004). Moreover, under societal aspects, the flourishing of BW in sci-fi imagery and the waves of panic triggered by global epidemics, suggest the power of deliberate disease in social imagination, but are also detrimental to a reasoned risk analysis.

Defining the risks of deliberate disease is challenging already from the definition of BW. The BTWC prohibits "microbial or other biological agents, or toxins whatever their origin or method of production, of types and in quantities that have no justification for prophylactic, protective or other peaceful purposes" along with relative means of delivery. BW are hence defined by the non-peaceful intention on using biological agents. This definition leads to distinctions along a number of spectra. First is the relationship between biological and chemical weapons (CW): biochemical threats range from classical chemical weapons to genetically modified biological agents (Pearson, 1990), and both the BTWC and the Chemical Weapons Convention (CWC) cover toxins and mid-spectrum agents acting on the nervous system. Second is the spectrum of effects: besides WMD, it includes "non-lethal" BW to induce incapacitation or psychophysical modifications; limited scope weapons; and weapons designed to cause terror or social disruption rather than physical harm. Third, the range of targets includes humans but also livestock, plants, the environment and materiel (Schaad et al., 1999; OIE, 2011a; OIE, 2011b). Fourth is the spectrum of sophistication, with crude BW such as those in pre-scientific era, military optimization ("weaponization") of natural agents, and advanced biowarfare possibilities. Finally, BW discussions have traditionally focused on pathogenic microorganisms, but debates about other biological agents used to cause harm have also occurred, such as on infestation (Sims, 2006).

3.1.1 State biological weapons programs before the BTWC

Conflicts have historically been accompanied by disease because of poor hygienic conditions, weakened health of populations, or lack of medical supplies. Despite references to ancient practices of tainting arrows or poisoning wells, it is difficult to talk of cognizant biological warfare before the nineteenth century. In his analysis of BW before WWI, Wheelis (1999b) sets out stringent criteria for considering historical examples of actual biowarfare.[163] The increased understanding of mechanisms of germ disease allowed a grasp on how to control it. During WWI, Germany carried out sabotage operations to infect Allies' livestock supplies (Wheelis, 1999a). France started a BW program in 1922, basing it on misperceptions of activities continuing in Germany.[164] A BW research program is also documented in Hungary in the 1930s, possibly linked with one in Italy (Geissler, 2001; Labanca, 2000).

Between 1931 and the end of WWII, Japan developed a vast program of BW development and use, including defensive and offensive measures carried in occupied Manchuria (Harris, 1999).[165] The UK BW program was more limited but also more scientific, and focused, in its offensive component, on anti-animal attacks.[166] In the 1950s, BW declined in importance in the UK, because of the nuclear deterrent and technical

[163] Accounts from the Middle Ages include episodes where attackers hurled dead bodies into besieged cities, such the siege on the seaport of Caffa in 1346; however evidence that outbreaks were caused directly and only by the catapulted infectious material is not conclusive. The only episode satisfying Wheelis' criteria regards an attack carried out by British traders and officials in 1763, when blankets from a smallpox hospital were included in a trade with Native Americans.

[164] This largely defensive program included research on a variety of pathogens, infesting insects, delivery methods, and dispersion tests (Lepick, 1999). The program, curtailed with the German occupation, resumed in 1947 but suffered lack of priority in comparison to nuclear weapons (Lepick, 2006).

[165] Operations led by the specialized Unit 731 included human experimentations, research and attacks using disease-carrying animals, artillery shellfire, aircraft spraying, and air balloons.

[166] Anthrax-laced cattle cakes were produced, while field trials of explosion-produced aerosolization (van Courtland Moon et al., 1999) were carried out on Gruinard island in Scotland, which would have been contaminated until the 1990s (BBC, 2001).

difficulties (Balmer, 2006).[167] Towards the end of WWII, the United States gained interest in BW, entering a collaboration with Canada and the UK. The program included research on anthrax, plague and turalemia, as well as anti-crop projects (van Courtland Moon, 1999). After the war, BW were overshadowed by nuclear in strategic policy, but the belief that the USSR was developing a BW capability supported the continuation of the program.[168] In the 1960s, US BW policy started to be reconsidered; factors included perceived limited military value and an increasing criticism of the use of anti-plant agents in Vietnam. In November 1969 the US declared the renunciation of its biological warfare program. Reasons for the decision included encouraging the adoption of an international ban to prevent proliferation, and sanctioning the separation between biological and chemical disarmament. US BW facilities were converted to civilian and biodefense, such as the United States Army Medical Research Institute of Infectious Diseases (USAMRIID). The latter focuses on preparedness against BW attacks, which became a key element in US defence and often requires secrecy, opening the sensitive issue of keeping offensive and defensive research - the former prohibited, the latter necessary - distinct.

3.1.2 State biological weapons programs after the BTWC

After the entering into force of the BTWC in 1975, three countries have been discovered as in breach of the Convention: the Soviet Union, Iraq and South Africa. Allegations of illegal activities also occurred on and by several states, however with no definite evidence or independent analysis of accusations (Furmanski and Wheelis, 2006).[169]

[167] Increasing disaffection towards BW, and the entry into force of the BTWC, moved the British program to a defensive-only nature.

[168] It researched ways to make agents more resistant to stockpiling and stress from delivery or meteorological conditions, and large area coverage tests were carried out with simulants (van Courtland Moon, 2006).

[169] Accusations included those on the US, Myanmar and Rhodesia (Furmanski and Wheelis, 2006; Dando, 2009b), Libya, Iran, Syria (Leitenberg, 2005); in many cases allegations were politically motivated propaganda or poorly sustained. Accusations with no substantive account included the Soviet, Chinese and North Korean ones against the US during the Korean War (Furmanski and Wheelis, 2006 p. 261), the US ones over Soviet mycotoxin use in Afghanistan (Furmanski and Wheelis, 2006 p. 275), and the Cuban accusations over infestation perpetrated by the US (Furmanski and Wheelis, 2006 p. 268).

The USSR had a limited interest in BW until the early post-WWII period (Bojtzov and Geissler, 1999), with an impetus after 1973.[170] Defensive activities as vaccine research were coupled with production of *Bacillus anthracis*, Marburg virus, *Yersinia pestis*, and the smallpox virus with offensive focus.[171] During the 1970s, suspicions rose in the West that the USSR was violating the BTWC; the most debated case became an anthrax outbreak in Sverdlosk in 1979, which killed at least 60 and was attributed by the Soviet Union to contaminated meat, but that further research by others attributed to a leak from a military biological facility.[172] After Russia's disclosures in 1992 on the BW programme and delays in implementing the BTWC, the BW complex was dismantled or redirected to civilian or defensive activities. However, Russia is still reluctant to openness on the fate of former military and biodefense facilities (Leitenberg et al., 2012).

In the 1980s, Iraq started a BW program focusing on obtaining capabilities for rapid production and deployment. Most information comes from the UNSCOM and UNMOVIC Commissions, which, however, could not reach a definitely clear picture (UNMOVIC, 2003). Production focused on botulinum toxin, aflatoxin and anthrax (Pearson, 2006), as well as anti-crop wheat cover smut (Dando, 2009b), to be deployed in operational warheads between 1990 and 1991. After the Gulf War, the UN Security Council (UNSC) required Iraq to destroy WMD and ratify the BTWC. Complete verification was difficult, as UNSCOM could not account for all estimated CBW (Wahlberg et al., 2000). UNMOVIC was able to recognize that Iraq in 2003 had no BW active program, even if it was not possible to exclude it had conserved the capability to restart it.

[170] During the Cold War most information on the program came from Soviet defectors, on whose accounts most details are still based (Alibek, 2008). Estimates report for up to 60,000 staff involved in the program, comprising the military and the ostensibly civilian organization Biopreparat, and tens of thousands of tons of agents produced, with at least a hundred tons supposedly ready for deployment (Domaradskij and Orent, 2006).

[171] Research introduced new scientific techniques such as genetic manipulation to improve effectiveness, insert antibiotic resistance, cause autoimmune reactions; and work on bioregulators.

[172] Later studies suggested the unusual pattern of infection originating from the military facility and confirmed the inhalation route of infection for anthrax (Meselson et al., 1994; Wampler and Blanton, 2001).

In the 1990s, materials disclosed by the Truth and Reconciliation Commission revealed a South African CBW program started in 1983, (Gould and Hay, 2006). Initiated to research protective measures, it evolved to offensive capabilities using commercial companies as front organizations. Research suggests that BW were intended for crowd control and assassination (Gould et al., 2002), while unsuccessful study of anti-fertility vaccines for the black population was also carried out. The post-apartheid De Klerk government, after introducing criminalization of BW, terminated the programme.

3.1.3 Bioterrorism and biocrimes

Biological weapons also attracted the interest of non-state actors; these cases include biocrimes and bioterrorism. The former exclude political or ideological goals, while the latter has been the subject of enormous attention especially since 2001, on the rationale that deliberate disease would be attractive for terrorists because of their relative accessibility in light of potentially devastating effects.

Well-documented bioterrorism acts against humans include the Rajneesh, Aum Shinrikyo and Amerithrax cases.[173] In 1984, the religious sect of Rajneesh contaminated salad bars with salmonella in a town in Oregon.[174] They failed in their goal, but the result was that hundreds were sickened. The group used simple ways to obtain, produce and disperse salmonella; the outbreak was noticed as unusual, but its intentional nature was not recognized until members of the sect confessed the plot (Wheelis and Sugishima, 2006). Aum Shinrikyo, an apocalyptic Japanese cult, attracted several thousands followers and had extensive financial resources. It planned destructive acts proclaiming the need to “purify society”. Beginning in the early 1990s Aum invested in a BW capacity, employing members with microbiology training. They obtained botulinum toxin and anthrax, however they failed to develop them due to ill preparation and bad management (Furukawa, 2011). Aum switched to CW, being successful in disseminating sarin in the Tokyo subway in 1995. The attack

[173] Accounts of early documented bioterrorism against animals include a small-scale campaign to infect cattle in Kenya by the separatist movement Mau Mau in 1952 (Carus, 2002 p. 63).

[174] The motivation was to incapacitate voters in a county election and gain freedom of action for the local cult’s commune.

killed thirteen and injured several hundreds; the cult was dismantled, and many members convicted for murder. In the US in 2001, letters containing weaponized anthrax were mailed to media and political figures. Twenty-two cases of anthrax were identified; five people died, and others suffered disability. The attack prompted a prophylaxis program, the shutdown of public facilities, decontamination and widespread panic. The strain of anthrax was matched with those in a flask at USAMRIID (Guillemin, 2011), the FBI closed the investigations only in 2010 identifying the sole culprit in a scientist from the biodefense lab, who had died in the meanwhile. Achievements of bioterrorism attacks suggest considering this threat in perspective. A global chronology of CBRN incidents identified 91 bio-related events between 1952 and 2005, including possession, threats of use or actual use, and mostly crude criminal use of biological materials (Mohtadi, 2006). Another compilation identified two thirds of CBRN incidents between 1900 and 1999 as hoaxes (Tucker and Sands, 1999). Indeed there are several challenges in the preparation of effective BW. These include obtaining a pathogenic strain; conserving, handling and growing it correctly (Leitenberg, 2005); determining the host range, routes of infection, minimal response doses, how to achieve targets, ensure survival in the environment, and overcoming immune systems and therapeutics (Zilinskas, 2000). This requires knowledge, time, equipment, organization and funds, which may be large obstacles for private actors. However, past failures do not necessarily predict the future, and the risk may be increasing in the last decades (Salerno et al., 2004). Technological advancements, which are positively impacting public health, are also making the above steps less complex. Also while the bioterrorism hype may have increased the attention of potential perpetrators, the enhanced preparedness, biodefense and legislation brought by policy attention may have prevented attacks in the last years.

3.1.4 The issue of dual-use

Formerly used to design military technologies transferred to civilian uses, the dual-use concept has today at least three dimensions: ostensibly civilian facilities actually intended for weapons development; legitimate equipment and agents that could be misappropriated and misused; and the generation and dissemination of scientific knowledge that could be misused (Atlas and Dando, 2006). While dual-use potential may be intrinsic in every technology, with life sciences the challenge is unique as equipment, technologies and materials applied to peaceful purposes could almost entirely be also applied to cause deliberate disease. As Tucker (2012) observed, defining dual-use control measures in biotechnology can be a double-edged sword: assigning them too narrowly would exclude potential threats, while doing it too broadly would put excessive restriction on innocuous technology. This is the dual-use dilemma in the life sciences, which was often debated on the occasion of publication of research such as those rendering an animal variant of the smallpox virus resistant to know vaccines (Jackson et al., 2001), or reconstructing the 1918 Spanish influenza virus (Tumpey et al., 2005).

3.2 Identification of deliberate disease risks

Optimal risk scenario identification defines a unique failure event in a detailed characterized system, pairing all possible sources of risk with all potential targets (Leung et al., 2004). This allows higher resolution in characterizing likelihood and consequences, as the more general a scenario, the less resolution can its characterization have. However, such a level of detail also leads to very large numbers of risk scenarios, making it impractical and calling for prioritization; furthermore, in our case we are interested in looking at broad deliberate disease risk scenarios as our aim is understanding if, and how could education influence them, rather than specific assessment.[175]

Deliberate disease risk scenarios are evolving. On the one side, there is a multiplication of potential threats: in the twentieth century, they mainly came from nation-states with political motivations and resources to develop BW programs. In the current context, the state-run BW proliferation threat is multifaceted with the assimilation of science and technology advancements in military programs, while non-state actors with increasing access to technology represent additional threats. These include terrorists acting for ideological motives, and others acting on private or economic reasons.

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[175] See for example Caskey et al. (2010) on biosafety risk assessment, where they limit to 13 biosafety risk scenarios identified.

There are also technological advancements constituting both challenges and opportunities in dealing with security risks. These may be categorized in new capacities, rapidity of developments, increased access, and convergence of different disciplines, that all allow beneficial progress but also challenge current instruments for preventing misuse (BTWC, 2012a; National Research Council, 2011a).[176] The rapidity of advancements in biotechnology outpaces other scientific fields.[177] At the same time biotechnology becomes widespread: more countries have advanced biomedical sectors; affordable commercial services allow students (Arsenic Biosensor Collaboration, 2013; Simonite, 2005) and amateur biotechnologists to perform activities formerly requiring expensive equipment and facilities, and to merge with growing trends of open technology. Biology is converging with other disciplines; bioinformatics allows working on models of biological systems and exchanging DNA sequences over the Internet. Biotechnology, thanks to sequences' banks and predictive models, crosses with engineering making development and production easier (Carlson, 2010).

A converging field that raised concern over ensuring it is only applied to peaceful purposes is neuroscience. Military interest in neuroscience falls under performance enhancement and degradation (National Research Council, 2009c; Royal Society, 2012), which both pose legal, political and ethical issues. Performance enhancement military applications may include brain-machine interfaces and actions on sleep, fatigue or fear (Tennison and Moreno, 2012). Performance degradation may include the

[176] Regarding capacities, for example, genetic engineering opens new production options for deliberate disease including the expression of toxic proteins, or using plants or animals as bioproduction reactors; systems biology may allow to target specific systems within organisms, in what have been termed Advanced Biowarfare Agents (Petro et al., 2003); gene synthesis makes it easier to construct agents; bioregulators to modify functions of the immune, nervous and endocrine systems (Kagan, 2001); microencapsulation allows a more precise delivery, including crossing the blood-brain barrier. At the same time, progress in bioforensics, biosensors, epidemiology, countermeasures and vaccine research, inter alia, improve the capacity to prevent and respond to BW.

[177] It has been argued for example that the DNA sequencing performance, a function of the number of sequenced base-pairs and cost, followed a pattern similar to the Moore's law (Carlson, 2003) for computational power - that the number of transistor per integrated circuit doubles every two years, but it is actually moving hyperexponentially.

development of CBW acting on the nervous systems, prohibited by international law, as well as incapacitants, chemicals or toxins with a temporary harmful effect.[178] In general, deliberate disease risks in other studies look at the risk of agent(s) to be acquired and used by a threat in an attack (Gaudioso et al., 2009; Sandia National Laboratories, 2014b).

3.2.1 Three deliberate disease risk scenarios

Based on these considerations, we identify three general deliberate disease risk scenarios from the spectrum of contemporary deliberate disease risks. The first risk scenario focuses on nation-states carrying out programs to cause deliberate disease, while the second and third scenarios look at bioterrorism carried out by non-state actors.[179] The second and third scenarios are different in that the second looks at the case of terrorists who do not have access to protected assets (materials and skills) seeking to obtain capabilities to cause deliberate disease including from public dual-use information; while the third scenario regards terrorists with direct access to materials or skills capable of causing deliberate disease, i.e. including an insider threat or compromised scientist component.[180]

Table 3 - Deliberate disease risk scenarios

No.	Threat	Scenario
1	State	Programs by nation-states to cause deliberate disease
2	Terrorist	Non-State actors seeking access to assets and/or capabilities (outsider)
3	Terrorist	Non-State actors with access to assets and/or capabilities (insider)

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[178] Incapacitants are so-called non-lethal weapons and pose their own ethical and legal challenges. The CWC includes in the permitted uses of toxic chemicals "law enforcement including domestic riot control"; while it does not define law enforcement, it is believed to be a larger category of riot control. Also the label of "non-lethal", as it suggests a "more humane" property, is a slippery legal and ethical concept, as lethality can be relative to doses, targets, and use in conjunction with conventional weapons (Davison, 2009).

[179] The three risk scenarios mainly focus on planned attacks directed to humans, among other targets that may also include property, animals, or the environment. While the focus on human targets of deliberate disease is a limitation, it should be noted firstly that human BW have historically gained the largest interest by threats, and that attacks on other targets would also have indirect consequences on humans.

[180] From the considered risk scenarios we hence exclude biocrimes, or deliberate disease acts by non-terrorist threats, such as those for revenge, assassination, personal gain or financial motives, as well as biosecurity risks beyond deliberate disease such as stealing of financially valuable assets, intellectual property rights frauds, counterfeit pharmaceuticals, etc.

3.2.2 Consequences of deliberate disease risks

The specific consequences of these deliberate disease risk scenarios depend on the events considered, but generally they can be from two categories or a mix thereof: consequences measureable in quantity or quality of human lives, and consequences measureable with economic losses.[181] Consequences mainly measured with human life parameters would include deaths, disabilities, illness, chronic diseases or reduced quality of life due to infection (Isukapalli et al., 2008; Hokstad and Steiro, 2006); or in terms of years of reduced life expectancy. Consequences mainly measured in economic parameters may include decontamination costs (Isukapalli et al., 2008), disruption of operations of critical infrastructures (Li et al., 2009) and recovery, or intellectual property damage. Some consequences of deliberate disease risks could be expressed in both quality of human life and cost parameters, such as public anxiety, fear, public "no confidence" in responders or the government, loss of reputation, and discomfort (Clevestig, 2009), disruption of an eradication program (Gaudioso et al., 2009), biodiversity loss, food supply instability (Stirling, 1999), as well as secondary infections. In a few cases, consequences, such as some permanent environmental damage, could go beyond a financial loss estimation (can be characterized as "inestimable"), and be a category in its own.

3.3 Characterization of deliberate disease risks

Risk characterization entails answering the questions "how likely is it to happen" and "if it does happen, what would be the consequences", i.e. determining the relative[182] likelihood and consequences of different risk scenarios. Some terrorist risk researchers regard "intentional harm" risks

[181] Assessors can decide to consider consequences from both categories at the individual or at the societal level, "where individual risk gives the probability of dying on a certain location, the societal risk gives a number for a whole area, no matter precisely where the harm occurs within that area" (Jonkman et al., 2003 p. 6).

[182] We have discussed before that risk characterization relies on values that can be objective, yet can only be relative to other risks, either contemporary or across time. It should also be noted that for security risks "it is often impractical to apply quantitative risk analysis to a large number of risk scenarios at this phase. In such a case, qualitative risk analysis offers an adequate alternative." (Leung et al., 2004).

as a product of threats, vulnerability and consequences (Willis et al., 2006; McGill et al., 2007; Paté-Cornell and Guikema, 2002). I think such an approach mixes layers of analysis, as characteristics of threats and vulnerabilities actually affect, among others, the likelihood of risks. Anyway, as I noted before, I am not focusing on providing another estimation of the relative values of likelihood and consequences for specific deliberate disease risk scenarios, but rather in identifying what factors contributing to them may be influenced by education.

Deliberate disease risk characterization has to look at characteristics of three factors: hazards, threats, and situations. Hazards are pathogenic biological materials; threats are actors with the intention to cause harm; and situations are the contexts where hazards and threats could cause harm. No deliberate disease risk may exist without any of the three, as a threat would not pose a biorisk without a biological hazard; a biological hazard would not pose a security risk without a threat; and neither can pose a deliberate disease risk without a target or occasions to carry an attack.[183] Factors that affect likelihood precede the occurrence of the considered adverse event with the potential to cause harm (a state or non-state threat acquiring BW capability or carrying a BW attack), while factors that affect consequences occur following that event. Characteristics of hazards largely affect consequences, while characteristics of threat and situation largely affect likelihood.[184]

3.3.1 Hazard and threat characterization

3.3.1.1 Hazard

It's common to find biological hazards categorized in "risk groups" (WHO, 2004; ABSA, 2014; European Union, 2000; European Agency for Safety and Health at Work, 2014), which are the results of characterizations only based on the hazard's factors. While pathogen risk groups are useful to

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[183] Obviously, a threat and a situation could cause other risks with access with other types of hazards, and biological hazards and a situation can cause biosafety risks without the presence of a threat.

[184] As an example, think to the risk of a terrorist group acquiring BW capabilities, within the second deliberate disease risk scenario considered. Consequence of infection will be influenced by the transmissibility and mortality of the pathogen. Likelihood will be influenced by the threat's means and opportunities to acquire materials and skills, by mode of delivery, weather, and especially available risk mitigation measures.

inform decision-making on managing biorisk, including deliberate disease risks, they cannot be considered the product of a complete risk assessment. Obviously, pathogen risk groups cannot account for specific threat or situation factors that would be different from case to case. Risk assessors should hence use risk groups "only as a starting point" (Caskey and Sevilla-Reys, 2015 p. 47) to consider all factors contributing to risk characterization, which may lead to a different risk assessment.[185] Hence, hazard characteristics may be reviewed within the general characterization of likelihood and consequence of deliberate disease risks.

Characteristics would include the type of pathogenic material (virus, bacteria, toxin, spores, fungi, etc); related sensitive information (research, procedures, formulae, genetic information, etc); the pathogen being naturally occurring or engineered (modified living organism or synthetic); the form in which it is stored (human sample, culture, dried spores, information); its quantity and concentration. Characteristics of the pathogen would also include virulence, morbidity, mortality, infectious dose, routes of infection, host range, dose-response models, available vaccines and therapeutics (National Research Council, 2004), its persistence including transgenerationally, recurrence and delay (Hohenemser et al., 1983), *sequalae*, endemicity, survivability (Gaudioso et al., 2009).

3.3.1.2 Threat

The necessity to consider the threat is what makes security risk characterization very different from safety risk characterization, as we have to include an intelligent actor. Characterization of the threat involves looking at motives, means and capabilities, and opportunities to cause deliberate disease. Some argued that motives would be the most important threat factor as it's the generative one of the intention to cause disease (Brown and Cox Jr., 2011).[186] Motives would be characterized by

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[185] For example, the risk associated with a pathogen from a "high-risk group" may be assessed differently by an organization in a situation when no credible threat exists, or where the pathogen is endemic in nature and potential threats have other opportunities to acquire it. Conversely, the risk associated with a "low-risk group" pathogen may be assessed relatively higher where the pathogen is not endemic and/or where there are inappropriate risk mitigation measures, leading to prioritizing it in terms of resource allocation.

[186] And a motivated threat can wait until they have means and opportunities.

intensity (Depoy et al., 2005) and nature, which should be considered by assessors. They should be analysed based on threat's known values and beliefs (Keeney and von Winterfeldt, 2010), and objectives can include causing casualties, fear, gaining publicity, revenge, etc.[187] Also a motive that may lead a threat to focus on one particular asset is if the asset has unique potential to cause harm, and/or if the target facility is unique as a source to acquire the hazard (Gaudioso et al., 2009). Threats' factors relative to means and capabilities, that may influence the likelihood of deliberate disease risks, would include funding, technical capacity, equipment, organization, and time. Finally, risk likelihood depends on the threats' opportunities to access hazards and related materials and information. A threat will be greatly facilitated by compromised personnel from a technical facility with access to hazards (insider threat), while different types and extent of opportunities may come from available dual-use materials and information, including publicly available research.

Certainly the characterization would be different of different factors of the state and the terrorist threats affecting risk likelihood in our three deliberate disease risk scenarios. In general, we can consider that means and opportunity factors are higher for state threats than for terrorist threats, but the latter may still find BW more accessible when compared with other WMD. Motives, on the other hand, would be lower for state threats than for terrorist threats, given that for the former the international stigma and prohibition regimes provide a greater obstacle and challenge, while for the latter the destructive and dreadful potential provide a potentially stronger incentive.

3.3.2 Situation characterization

Characteristics of the situation that impact (mainly) consequence of deliberate disease risks pertain to the context in which the adverse event happens. In the case of a BW attack, for example, they include position, spatial extension (Hohenemser et al., 1983) and timing of the release or contamination, and weather conditions such as temperature, humidity,

[187] We focus on motives that may be linked to the deliberate disease risk scenarios and the possible consequences discussed above. Other threat's motives may obviously include money, intellectual property, etc.

precipitation and wind. Characteristics of the target would also be part of situation characterization with population distribution, human activity patterns and health conditions (Isukapalli et al., 2008). Another situation characteristic is the mode of delivery, such as aerosolisation, spraying, lacing of food and drinks, use of animal vectors or crude dispersion. This and other characteristics may increase the risk depending on the hazard characteristics: for example the risk involving a pathogen infecting through inhalation will be higher if the chosen mode of delivery is aerosolisation versus lacing (or, say, by adding something to water) contamination. However, the situation characteristics that would most influence deliberate disease risks are the available risk mitigation measures to reduce system vulnerabilities.

3.3.2.1 Deliberate disease risk mitigation measures

Risk mitigation measures primarily aim at lowering likelihood of an event happening, such as rules, good practices and physical barriers, but in some cases can focus on lowering consequences (such as the case of therapeutics).[188] Deliberate disease risks need the web of prevention of measures targeting situations both within and beyond the physical space where hazards are present (such as laboratories), as well as risk scenarios involving state or non-state threats. In the following paragraphs I will discuss deliberate disease risk mitigation measures aimed at state BW programs; laboratory biosecurity risk mitigation measures; and security awareness and culture risk mitigation measures.

3.3.2.1.1 The international prohibition regime on biological weapons

The international prohibition regime on BW is a key component of the web of prevention and a group of deliberate disease risk mitigation measures primarily focused on reducing likelihood and consequences of the deliberate disease risk scenario with a state threat, but also seeing states cooperating to reduce deliberate disease risks from the terrorist threats. In the nineteenth century, the prohibition on poison as a weapon was codified with the Brussels Convention of 1874 and conferences in The Hague of 1899 and 1907. The horror of the use of CW in WWI led to

[188] In some cases, even the implementation of consequence mitigation measures lead to practices lowering likelihood as well: see helmets reducing not only motorcycle fatalities (risk consequence) but crashes (risk likelihood) as well (Lee, 2015).

efforts to reach international agreement on limiting their use, and in 1925 the Geneva Protocol prohibiting use was signed.[189] While membership of the Protocol grew to 140 parties,[190] the prohibition on CBW use is now considered part of international customary law (Sims, 2006) even for those states that have not lifted reservations (i.e. limiting conditions to the commitment to the prohibition) or are not Parties to the treaty. The Protocol did not prohibit production of CBW; on BW this was reached with the first international agreement to ban an entire category of weapons, the BTWC of 1972.[191] The BTWC obliged signatories to destroy existing arsenals; take national implementation measures; consult in solving problems; cooperate in investigations arising from complaints to the UNSC on alleged use; negotiate a CW disarmament treaty; and pursue cooperation on peaceful uses of microbiology. Membership of the BTWC now[192] includes 175 States Parties; universalization of its prohibitions remains one of its main objectives.

Despite not providing systems for verifying that Parties were living up to their obligations, nor an organization to oversee implementation, the treaty mandated a Review Conference after five years, and such Conferences have been held in similar intervals, establishing a mechanism to develop a "BTWC regime" (Sims, 2001). The First Review Conference already showed the problems of lack of reliable verification, as it took place amidst the allegations on the Sverdlovsk incident. Addressing the compliance issue, the 1986 Second Review Conference established a system of Confidence Building Measures (CBMs) to "prevent or reduce the occurrence of ambiguities, doubts and suspicions, and in order to improve international co-operation" (BTWC, 1986). The Third Review Conference

[189] Language on "bacteriological methods of warfare" was inserted in the final document on the proposal of Poland (Mierzejewski and van Courtland Moon, 1999). Later interpretations considered the term "bacteriological" applicable to all BW (Goldblat, 1971).

[190] As of August 2016.

[191] Difficult negotiations on a CBW prohibition had been held in the 1960s, on British proposals; the US renunciation of BW, and a new Soviet openness to discuss BW separately from CW, unblocked them. The final text of the Convention, however, was less ambitious than previous drafts: it didn't include a prohibition on use, which would have reinforced the Geneva Protocol, and it did not have a system to verify compliance. Still, it completely prohibited all activities "related to possession" (Sims, 2006) of BW.

[192] As of August 2016.

mandated a group of Governmental Experts known as VEREX to investigate technical verification measures. The group identified 21 possible measures concluding that, while none alone could determine compliance, in combination they could be useful in improving transparency (BTWC, 1993). At that point, a Special Conference commissioned a political Ad Hoc Group (AHG) to produce a proposal on a legally binding protocol to strengthen the Convention. The AHG worked among tensions on verification, transfer of sensitive technology, protection of commercial information, and access to science and technology. The “composite text” tabled by the AHG chair in 2001 had still to face several issues among States Parties. The US rejection of the text, led by the conviction that it would not have provided reliable verification, and hardened by the anthrax letters case and doubts of other delegations, prevented the finalization of the process. With the failure of the protocol, new modes to keep alive the cornerstone of the international prohibition on BW had to be devised.

The resumed Review Conference in 2002 established an Inter-Sessional Process (ISP) of annual meetings “to discuss and promote common understanding and effective action”. Started as what was seen by many as a mere fill-in, the ISP served to be a useful, even if minimal, solution. States Parties discussed national implementation measures, security of pathogens, disease surveillance, and codes of conduct for scientists. The Sixth Review Conference agreed to establish a second ISP and a small “secretariat”, the Implementation Support Unit (ISU). New topics included legislation, cooperation, biosafety and biosecurity, education, and assistance in case of alleged use. The ISP accomplished a number of achievements: States Parties engaged in discussions and exchange of best practices; the variety of national implementation measures needed was underlined; the object of the BTWC was recognized as increasingly multidisciplinary; representatives of the scientific communities were engaged; universalization of the Convention and participation to CBMs were annually monitored. At the same time the limitations of the ISP became clear: the lack of decision power in between Review Conferences; the absence of an organization supporting the Convention; the inconsistency of changing topics annually. The Seventh Review Conference in 2011 should have addressed these limitations, but had mixed results. States Parties could not agree to strengthen the ISU, nor to giving limited decision power to the Inter-Conference meetings, however they decided on a third revamped ISP for 2012-2015.[193]

The BTWC would still be the keystone of the prohibition regime, and one of the main open issues remains verifiability. The example of UNSCOM allowed unravelling a covert program (Smithson, 2011), but also indicated that definite verification is difficult if not impossible. Since the failure of the BTWC protocol in 2001, the issue of verification has been kept marginal in the Convention, even if some States Parties underlined it remains their long-term objective. However recently there have been new proposals on how to reassure compliance and transparency. Components of the failed protocol have been analysed on how they could be adapted to voluntary mechanisms: supporting a declaratory regime; extending the UN Secretary General's Mechanism for investigation on alleged use to alleged production; reciprocal visits to biodefense facilities (Lennane, 2011). The importance of CBMs has been stressed, and some States Parties now make their CBMs publicly available.[194]

Almost sunk in 2001, the BTWC was able to find innovative ways to address security issues of life sciences. It is also today very different from other WMD control regimes. Using what has been termed an "evolved networked model", it brings together "all the various stakeholder communities, which then implement the treaty through their initiatives and efforts" (Millett, 2010), and it gained input from scientific communities, academia and civil society. The Convention made clear that its prohibitions cover any advancement and "naturally or artificially created" pathogens (BTWC, 2006), and it is also a forum to nurture collaborations and

[193] The new ISP included three Standing Agenda Items (SAIs): cooperation and assistance, review of science and technology, and national implementation, kept for the whole period; CBMs reformed to allow larger participation and information sharing; and a database system to facilitate requests and offers of cooperation.

[194] Furthermore, the US announced in 2011 an initiative inviting other states parties to visit US biodefense facilities (Rodham Clinton, 2011). France presented a detailed analysis on a possible peer review system of compliance, inspired by existing international mutual monitoring systems (France, 2012). A group of States proposed a discussion on defining "what constitute compliance" and "how to demonstrate" (Australia et al., 2012), which received considerable feedback (Japan, 2013; UK, 2013).

technological transfers. However, it remains remarkable that the main international instrument to prevent malign exploitation, and promote peaceful cooperation, in the face of advancing technological endeavour, has few resources in comparison to the nuclear and the chemical regimes.

The 1993 CWC is also part of the regime on BW as it covers toxins from biological organisms. The CWC is almost universal with 192 States Parties, includes a precise and legally binding verification system, and is supported by an organization monitoring destruction of stockpiles, re-emergence of weapons, and international cooperation on peaceful uses of chemistry. International legal prohibitions are completed by other elements: states defeated in WWII are bound by prohibitions on BW in the treaties stipulated between 1947 and 1956 (Sims, 2006); the UNSC Resolution 1540 of 2004 binds all UN states to refrain from providing support to non-state actors attempting to acquire CBRN weapons; export control regimes control transfers of dual-use items, such as the Australia Group focusing on CBW, and the EU dual-use export controls (European Union, 2009; Australia Group, 2013).

3.3.2.1.2 Laboratory biosecurity risk mitigation measures

Laboratory biosecurity risk mitigation measures would primarily influence the likelihood of non-state threat deliberate disease risks, as we assume that the organization to which the facility pertains is not voluntarily involved in a state program of research and development of life sciences and technology to cause harm. In this case, the facility is considered as a target that should be defended against a terrorist threat because it has assets valuable for those with the intention of deliberately causing disease, for example because it works with hazards or has information necessary to weaponize a hazard.

Laboratory biosecurity risk mitigation measures couple with laboratory biosafety risk mitigation measures within the laboratory biorisk management framework.[195] Laboratory biorisk management approaches

[195] Laboratory biosafety measures are primarily designed to lower likelihood and consequence of biosafety risks, i.e. risks of accidental and unintentional nature. However, many biosafety measures are also effective in mitigating biosecurity risks. Furthermore, an approach to mitigation that is based on risk assessment can be easily applied to different types of risk, so better capacity on

(WHO, 2004; Astuto Gribble et al., 2015) reprise hierarchies of mitigation measures from the occupational health and safety literature (Boyle, 2008; OSHA, 2008) that ranks categories of measures based on their effectiveness in mitigating risk.[196] The category of most effective biorisk mitigation measures is elimination of the hazard or its substitution with a less pathogenic strain (Gressel, 2005), but this may clearly have unacceptable impacts on science needs and operations, and is often not viable. Second are engineering controls, or physical modifications and devices that decrease risk likelihood, like containment facilities, cabinets, filtration systems, locks, doors and fences, cameras, biometric access controls, etc. Engineering controls have the advantage of being predictive and reliable in their functioning; however they may be costly, complex and depend on maintenance and correct operation that often requires specific capacities. Third, administrative controls are rules and policies issued by management with the authority to do so. They have the advantage of establishing clear standards but depend largely on the recognized authority of the issuer, need enforcement and to be efficiently communicated. Fourth, practices and procedures codify in detail practical behaviours demonstrated to lower risk likelihood. Practices have the advantage of being standardized so to lead to the same results;[197] but depend on the human factor and may need extensive training. Fifth, personal protective equipment (PPE) are devices worn by personnel to lower the likelihood of personal exposure. PPE are relatively easy to use but only protect the wearer, may be uncomfortable, and also need training for proper use. Specific biorisk mitigation measures can relate to different categories of the hierarchy: for example, a biorisk incident preparedness

biosafety risk spills over to improving biosecurity risk management. Finally, both laboratory biosafety and laboratory biosecurity risk management are integrated in the laboratory biorisk management framework, including the categories of risk mitigation measures. Technical and professional bodies have developed international standards and guidelines to address biorisks at the level of laboratories (WHO, 2004; WHO, 2006; CEN, 2011).

[196] The more effective measures in reducing likelihood and consequence of risk are not necessarily the more efficient choice for all facilities. That will depend on factors such as financial resources available, training, maintenance, equipment, organizational culture etc. Identification of the most appropriate complex of risk mitigation measures is a task of risk assessors.

[197] Standard Operating Procedures (SOPs) lead to the same results when performed by different people with the same inputs and in the same context.

and response system would include engineering controls such as first aid kits or quarantine and containment facilities; administrative controls, including laws and regulations; practices and procedures on maintenance, evacuation, or communication with external emergency services; and specific PPE to use in case of incident. Also, increased capacity is a key risk mitigation measure influencing risk likelihood, that is relevant at all levels of the risk mitigation hierarchy.[198]

Specifically on laboratory biosecurity risk mitigation measures, these have been categorized in five areas or pillars (Salerno and Gaudioso, 2007). Physical security practically prevents (or at least deters or delays) threats'[199] access to assets through barriers and access controls. Personnel management and reliability focuses on the likelihood of insider threat and includes background checks and monitoring. Material control and accountability involves keeping track of all material assets employing a variety of inventory procedures. Transportation security regards making sure that only authorized persons have access to the assets while moving them from one facility to another. Information security focuses on protecting sensitive information on the assets, or the sensitive information asset itself. Finally, the security awareness pillar is presented as an underlying necessary component of any complex of laboratory biosecurity risk mitigation measures, as it implies understanding the rationale and importance of measures and commitment by all personnel. In this sense, laboratory security awareness would contribute to an organizational culture similar to organizational safety cultures or climates.[200] Pillars of laboratory biosecurity risk mitigation are related to the general hierarchy of categories of laboratory biorisk mitigation measures, as illustrated in the table below. All measures are factors that primarily influence the likelihood of (mainly non-state) threats acquiring the hazards and the capabilities to

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[198] Such as in the capacity of managers to design, issue and communicate relevant policies; or of staff of correcting operating or maintaining equipment, perform a task safely and securely, or correctly choosing and rapidly donning and doffing PPE.

[199] As a reminder, "threat" is here used to indicate a persons, or group of people, intent on causing harm, as distinguished from "hazard" while both originative causes of risks.

[200] Based on organizational management, values, norms, activities and/or history to shape employees behaviours or outcomes (Guldenmund, 2000), commitment of top management, collaboration with colleagues, regular incident reporting and communication (Reader et al., 2015).

inflict deliberate disease, and hence would reduce especially the deliberate disease risks in the second and third considered risk scenarios.

Table 4 - Laboratory biorisk mitigation measures categories and laboratory biosecurity pillars

Laboratory Biosecurity / Hierarchy of Mitigation	Physical Security	Personnel Management and Reliability	Material Control and Accountability	Transport Security	Information Security	
Elimination						Security Awareness
Engineering Systems	X		X	X	X	
Administrative Controls	X	X	X	X	X	
Practices and Procedures	X	X	X	X	X	
PPE			X	X		

3.3.2.1.3 *Risk mitigation beyond the laboratory*

The inclusion of "security awareness" underlying laboratory biosecurity risk mitigation suggests that technical-only measures are insufficient to effectively reduce likelihood and consequence in deliberate disease risk scenarios.[201] The security awareness pillar presented by Salerno and Gaudioso (2007) however, would not have to be limited to technical facilities where either assets (hazards or information) are, or practitioners work, and the description of risk scenarios involving dual-use suggests it should not.

Indeed measures to reduce likelihood in deliberate disease risk scenarios would have to go beyond those of laboratory biorisk management and truly encompass the web of prevention of deliberate disease. The web should include measures issued and implemented not only by technical laboratories or governments, but also professional associations, editors, academia and other scientific organizations (Feakes et al., 2007). The web extends to regulations ("administrative controls") in various issue areas. At the national level, this includes appropriate legislation and regulations. Public health and disease control are another key element to prevent, detect and respond to deliberate disease; the implementation of the International Health Regulation (WHO, 2005) is important to assure internationally coordinated preparedness.

201 Also note how "effective refresher training" is presented as first mitigation measures in risk governance by Gaudioso et al. (2009).

Especially in the US there have been efforts in designing administrative controls to mitigate the risk of dual-use in the life sciences. A 2004 report by the National Research Council (National Research Council, 2004) identified seven classes of experiments posing particular concern.[202] A subsequent report (National Research Council, 2006) focused on the impacts of scientific advancements and future risk characterization, concluding that the focus on "traditional" biowarfare agents was "dangerously narrow". The National Science Advisory Board for Biosecurity (NSABB) identified a subset of research labelled Dual-Use Research of Concern (DURC): "research that, based on current understanding, can be reasonably anticipated to provide knowledge, products, or technologies that could be directly misapplied by others to pose a threat to public health and safety, agricultural crops and other plants, animals, the environment, or materiel" (NSABB, 2007). However, even this guidance framework did not prove optimal in front of growing challenges of dual-use, a major illustration being the case of the H5N1 gain of function experiments. In 2011, a Dutch team announced research showing how the avian influenza virus was rendered transmissible among ferrets, an animal model for humans. A similar independent American study was also being published.[203] In the US, the NSABB for the first time advised against the detailed publication of the studies. The international research community decided a moratorium on influenza experiments, and the WHO convened a conference on dual-use (WHO, 2012). After the WHO recommended in favour of publication, the NSABB reversed its decision and the papers were published in their entirety. In the meanwhile the Dutch government had applied export controls regulations on dual-use against the "export" of the research manuscript, starting a judicial quarrel with the researchers. The debate ignited by the H5N1 experiments highlights limits of country-based administrative risk mitigation measures to dual-use in rapidly advancing and globally interconnected research. Those experiments were funded by the US National Institute of Health: an

[202] Importantly, good examples of completely legitimate research can be found for each of those categories.

[203] The natural avian influenza virus has a high mortality rate but is not directly transmissible among humans: those experiments allowed understanding if and how the virus could mutate, but also created a new potentially dangerous organism.

improved oversight system could intervene earlier in the research process, but also similar scientific activities carried out by private institutions would be less likely to be detected by regulatory agencies.[204]

So widespread security awareness in the scientific community would itself be a factor influencing the likelihood of deliberate disease. Research ethics have also been described as a factor to reduce the likelihood of deliberate disease risks, proposing decision-making frameworks (Miller and Selgelid, 2007) that may apply to both the first (in case of scientists working in governmental research programs) and third risk scenarios. It has been argued that duties such as stopping research, limiting publications, or communicating with authorities should be shared between scientists and institutions (Ehni, 2008), and that dual-use should become the object of collaborative ethical deliberations (Bezuindenhout and Rappert, 2012). A precautionary principle[205] to refrain from activities of potential high risk has also been proposed (Kuhlau et al., 2011). At the same time, the opportunity of applying largely Western-based ethical principles to global biomedical fields is discussed (Bezuidenhout, 2014). A statement by the Journal Editors and Authors Group recognized that "on occasion an editor may conclude that the potential harm of publication outweighs the potential social benefit" (Journal Editors and Authors Group, 2003), similarly to some professional codes of conduct (IASB, 2009; EuropaBio, 2016). These latter examples would primarily have an impact on the second risk scenario.

3.4 Impact of education on characterization of deliberate disease risks

Given the above discussion of hazard, threat and situation factors that affect relative likelihood and consequences of deliberate disease risk scenarios, what factors could education influence, that would reduce likelihood and/or consequences, and how?

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[204] In 2013, a new Chinese study created over a hundred combinations between the avian flu and the H1N1 human influenza viruses (Zhang et al., 2013).

[205] One exemplar enunciation of a precautionary principle is that from the 1992 Rio Declaration on Environment and Development, stating that "where there are threats of serious irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (UNCED, 1992 p. 879).

Education that improves capacities on material control and accountability security, for example, would reduce the opportunity of a threat to access hazards. Similarly, education on the dual-use issue and on scientists' responsibilities in assessing risks deriving from distribution of research results would lower the opportunity for a threat to access and exploit dual-use information. Education that includes the history of, and the prohibitions on, BW, as well as the implications for responsible scientists, would reduce the availability of scientists to be employed in state programs, and increase their ability to recognize the offensive nature of applications of life sciences, hence potentially reducing the risk likelihood in the state threat scenario. On the other hand, such awareness of deliberate disease risks and of security measures would reinforce the prohibition for the individual and also increase their capacity to recognize insider threats, hence having the potential to reduce the likelihood in the third risk scenario. Increased and widespread capacity on laboratory biorisk mitigation measures, including laboratory biosecurity measures, would influence the impact on both hazard and situation characteristics. Furthermore, a risk mitigated through education would decrease the pressure for adopting "harder" administrative controls that could slow down and potentially hamper research, making it easier to work on research such as that on vaccines and therapeutics when is safe and secure to do so. These measures would impact both likelihood and consequence for all three deliberate disease risk scenarios (see Table 5).

Ultimately and generally, education would reinforce and spread a norm that prevents and safeguards scientists to indirectly contribute to (raising the factors affecting them) the risks of deliberate disease, and commits scientists to actively prevent those risks (lowering the factors affecting them). This way education has the potential to reduce, primarily influencing likelihood, the risks of deliberate disease by state and non-state threats.

Table 5 - How education could impact risk likelihood and consequence factors[206]

	Hazard Factors	Threat Factors			Situation Factors
		Motives Factors	Means Factors	Opportunity Factors	
Likelihood	Capacity on laboratory biorisk management measures	Instill the ethical norm of prohibition of deliberate disease in the individual		Applying physical security and MC&A	Ability of scientists to recognize the offensive nature of a program; willingness and availability of being employed in a BW program (whistleblowing)
				Responsible management of dual-use research	Capacity on laboratory biorisk management measures
				Recognizing insider threats	
Consequence	Make “hard” or top-down risk mitigation measures less necessary and speed-up R&D on vaccines and therapeutics				

3.5 Evaluation of deliberate disease risks

As presented in the previous Chapter, risk evaluation is an integral phase of risk assessment and a key step between characterization and taking actions to mitigate risk (Caskey and Sevilla-Reys, 2015). While risk characterization can be objective, yet relative and with the caveats expressed earlier, risk evaluation is subjective as it depends on the risk acceptance of risk assessors. The same characterized risk can be evaluated higher or lower[207] by different risk assessors. So what factors would affect risk evaluation, in particular in the case of deliberate disease risks; who would evaluate deliberate disease risks; and how could education affect risk evaluation?

3.5.1 Factors in evaluating deliberate disease risks

A widely used approach to risk evaluation is relying on cost/benefit ratios (Hokstad and Steiro, 2006), setting risk acceptance using a comparison between the reduction of risk likelihood, and consequence, and the use of resources to do so. Some mitigation measures would require larger investments than others in terms of funding, time and staffing. A relatively cheap and easy mitigation measure could in some cases greatly reduce risk, while the marginal risk reduction of additional mitigation measures

[206] Orange: state threat (first risk scenario); Green: non-state outsider threat (second risk scenario); Blue: non-state insider threat (third risk scenario); Purple: multiple risk scenarios.

[207] “High” or “low” if comparing within pre-determined scales.

may be smaller below a certain risk level.[208] Indeed a popular risk management principle is “do the very best you can”[209] with available resources, not least because “the use of economic, technical and management resources to abate one specific hazard may have the practical consequence that those resources are not used to abate another, perhaps similar, hazard” (Hattis and Minkowitz, 1996 p. 108).[210]Common risk evaluation factors that may be particularly relevant for evaluating deliberate disease risks may include voluntarity, economic incentives, reversibility and cognitive factors. Voluntary risks are accepted more easily than imposed ones, as they are associated with positive feelings, benefits and enjoyment, or because it is felt that the choice can be reverted if risks turn out to be higher than expected (Vrjling et al., 1995 p. 246). Connected to voluntarity is access to information, as people with clear information on risk characterization would be more likely to accept risks (Hattis and Minkowitz, 1996). This may explain why unlikely deliberate disease risks are often highly evaluated by risk assessors, given the lack of information primarily on threats factors. Economic incentives may raise acceptance, including the possibility of insuring against risk. Irreversible consequences are more likely to lead to lower risk acceptance (Haimes et al., 2002). Risk assessors, including the public in general, tend to be consequence-averse and evaluate higher those risks with relatively large consequences despite relatively little likelihood, as well as evaluating higher those risks originating from new hazards, including new or unknown pathogens. These cognitive factors (Lee and Lemyre, 2009) all contribute to lower acceptance and higher evaluation of deliberate disease risks. Cognitive factors may also include “perceived” characterization, which would different from evaluation, as in the former risk assessors “wrongly” characterize the relative likelihood and consequence of various risks. In terms of possible measurements of risk acceptability, proposed metrics

[208] And the only risk mitigation measure bringing the risk to zero would be the elimination of the hazard.

[209] Or bringing the risk “as low as reasonably possible”.

[210] Note how here “hazard” is used as we use “risk”.

may include increase of consequence probability,[211] or efficiency measured in invested and earned lifetime.[212]

3.5.2 Who evaluates deliberate disease risks

Evaluators of deliberate disease risks include, at different levels, individual scientists, management of scientific organizations, the public, and political decision-makers. In many cases, some risk evaluation is performed at the level of national or international policy-makers that issue rules or regulations dictating “a minimal level” (Caskey and Sevilla-Reys, 2015 p. 50) required for risk mitigation. In addition, individual scientists or scientific organizations have to make risk evaluation decisions on specific deliberate disease risks, often combining the scientific evaluation with security and intelligence input (WHO, 2006). Anyway in the case when an assessor, such as a public health laboratory, has to take laboratory biorisk management decisions to mitigate a specific characterized deliberate disease risk, it will have to take into account the community’s evaluation. Indeed “the most stringent of the *personally* and *socially* acceptable level of risk determines the acceptable level of risk” (Vrjling et al., 1995 p. 250, emphasis in the original).[213] Education can hence have an impact on evaluation via giving practictioners the tools to inform both the community and political decision-makers to make informed evaluation decisions; and to understand what factors can influence risk characterization that will determine necessary risk mitigation measures.

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[211] For example, a deliberate disease risk could be defined as acceptable if it adds “less than 1% to the already existing probability of death” (Vrjling et al., 1995 p. 249).

[212] Lind (2002), with his time principle of acceptable life risk, argues that “a measure of acceptable risk should be based on human values and expressed in human terms. The cost of life saving is not so many dollars; rather, the cost of a dollar is so much life”, so “a prospect to save life or produce wealth is preferable in comparison with an alternative if the net increase in quality-adjusted life expectancy is greater than the increased work time. That is, a prospect is said to be preferable to an alternative if its efficiency relative to that alternative is greater than one”.

[213] If the risk evaluation from the community is higher than the scientists’ one, the latter may have three options: apply additional mitigation measures until the characterized likelihood and consequence are lower and lay within also community’s acceptance; educate the community to correct a “wrong” characterization of relative risks; or introduce factors to modify the community’s evaluation and raise their risk acceptance. Otherwise, they may not be able to operate.

3.6 Conclusions

This Chapter discussed the risks of deliberate disease, applying the framework presented in Chapter 2. The possibilities of deliberate disease have been presented in a historical and comparative perspective. The challenges of defining deliberate disease risks became clearer, as I presented concepts and a concise history of biological weapons, as well as of biocrimes and of dual-use, and discussed the role of scientific and technological advancements. For an assessment strategy of deliberate disease risks, I went through firstly their identification and explained why I choose three specific possible risk scenarios: one with state threat; one with non-state outsider threat; and one with non-state insider threat. Subsequently, I discussed characterization of deliberate disease risks giving reasoned examples of factors that may influence likelihood and consequence, and ascribable to the hazard, threat or situation components. I explained the limits of characterizations based on “hazard risk groups”; motives, means, capabilities and opportunities of threats; and the range of mitigation measures, including the international prohibition regime on biological weapons, and risk mitigation within and beyond facilities. I then argued what factors generally presented as characterizing risks have the potential to be influenced by education under the three considered deliberate disease risks scenarios. For example, education could improve capacity on laboratory biorisk management measures, thus impacting on hazard factors and reducing risk likelihood under all three scenarios; it could instil the ethical norm of prohibition of deliberate disease thus impacting on threat factors and reducing risk likelihood under the non-state insider threat scenario; it could introduce responsible management of research with dual-use potential thus impacting on threat factors and reduce risk likelihood under the non-state outsider threat scenario; or could increase the potential for whistleblowing thus impacting on situation factors and reduce risk likelihood under the state threat scenario. I also discussed risk evaluation, what factors could affect this explicitly subjective portion of risk assessment, and how education could inform evaluation. In the following Chapter, I will introduce the analysis of securitization of education and then, in Chapters 5 to 9, integrate the research components of security, risk and education. In that sense, I will discuss if and how education could be designed and evaluated to influence risk factors as it was introduced in this Chapter.

4. Education as a security tool

This Chapter analyses the securitization of education as a security tool to deal with deliberate disease risks. The first and second paragraphs explain the concept of scientists engagement, which includes education, and how it has been co-opted by security actors as a strand of the web of prevention. Subsequently, the Chapter presents an overview of attempted securitization moves in chronological order, or how education entered in the traditionally disarmament toolbox of preventing BW and deliberate disease, with particular attention to the BTWC context: before the 2005 BTWC meetings on codes, between 2006 and the 2008 BTWC meetings on education and awareness-raising, and between 2009 and 2015. Calls for education are analysed and evaluated applying categories of the historico-political securitization approach.[214] Finally, open questions on education as a security tool for mitigation of deliberate disease risks are discussed, with particular attention to roles, contents and audience of education; implementation in higher education systems; and the issue of – assuming success of the securitization moves – evaluating the actual impact of education on both learning and risks.

4.1 Engagement of scientists

Educating scientists on security issues is one component of a policy that can itself be considered a component of the web of prevention, i.e. “engagement of scientists”. This generally means to address, rather than the protection of physical hazardous components such as materials or equipment, the knowledge that may raise security concern when applied for non-beneficial purposes.

The terms “scientists engagement”, “science engagement” and “security engagement” have been used in a variety of contexts to indicate a range of activities, not limited to security concerns or to the life science subject matter.[215] Usually, when promoters of the engagement are scientists, the term refers to “scientists working together with a shared understanding that objectives include both science and relationship-building, and where there is a clear, if sometimes

[214] Which looks at securitizing actors; intended audiences; referent objects; securitizing arguments; speech act discursive devices; proposed security measures; and post-speech act acceptance and implementation.

[215] Activities may include outreach and education of the public about science; but also to attract people to science careers; and foster relations, exchanges or partnerships involving science and technology between public or private actors nationally or internationally.

unstated, agreement that none of the participating parties are policy representatives of their country" (Seo and Thorson, 2013). The US National Academy of Sciences referred to scientific engagement as "the work of individual scientists who seek to contribute to global understanding and human welfare" (National Research Council, 2011b p. 1). This conceptualization of "engagement" at the international level is connected with "science diplomacy".[216]

"Security engagement" has also been used, including in relation to the WMD and CBRN security discourses. However in this case, the promoters and subjects of the engagement are political, state-level actors. An example is the Global Security Engagement label used for the model of the Cooperative Threat Reduction programs of the United States (National Research Council, 2009a). In this case "engagement" denotes a departure from subordinate, donor-recipient relations among States, to partnerships where challenges, risks, resources and solutions are shared.

"Scientists engagement", in the conceptualization that emerges from the CBRN security policy discourse, is promoted by both state-level actors and security-interested civil society, and is directed towards the global scientific, technological and academic communities. It regards the forging of relationships between the traditional depositaries of security policy (nation-states), on one side, and the private and civilian actors who hold the knowledge to understand foreseeable risks in technology and contribute to design and enforce security policies. "Scientists engagement" aims at the inclusion of scientists into security policy discussions, and includes activities such as education, training, development of codes of conduct, inclusion of security considerations in responsible conduct of research, outreach to scientific communities, their inclusion in security policy processes and events. Scientists engagement not

[216] "Science diplomacy" was largely explored especially during the Cold War and on nuclear science issues, and is about allowing people to use science in order to cross geopolitical boundaries, and about the independent relationships in the international scientific community to facilitate communication between states and cultures in the absence of official channels. The history of science diplomacy (Royal Society, 2010) demonstrates the value of these relations as a "deep water anchor" and open channel that would allow respectful and durable international relations at non-political levels, even when the latter are in crisis. One historical example of this type of "engagement" is the 1975 Asilomar conference, when scientists and representatives of civil society gathered to discuss the safety and health risks of creating new organisms using recombinant DNA techniques (Berg et al., 1975; National Research Council, 2013).

only acknowledges that the capacities of science and technology communities are essential for effective security policies, but also promotes that a proper engagement (rather than, for example, a mere consultation) is necessary to ensure that those communities accept to participate to the design of such policies. This approach would be one that "allows scientists to perceive themselves as actors engaged in socially beneficial activities which could be misused and offers them an identity as 'guardians of science' in the fight against BW and bioterrorism, rather than the passive recipients of bureaucratic regulations" (McLeish and Nightingale, 2007 p. 1654).

4.2 History of scientists engagement in security issues

It was with the end of the Cold War that "scientists engagement" was increasingly used in security discourses, mainly in dealing with the WMD legacy of the collapsed Soviet Union.[217] Engagement was, besides disarmament and dismantlement, one of the keywords of the Cooperative Threat Reduction program that the US established in 1991 (National Research Council, 2009a), even if during the 1990s the main focus of CBRN security programs regarding scientists was "redirection", or reemployment, of former weapon scientists to civilian activities.[218]

In 2002, the G8 launched (G8, 2002) the Global Partnership Against the Spread of Weapons and Materials of Mass Destruction (G8GP). The Partnership initially focused on physical dismantlement of risk sources like chemical weapons stockpiles and nuclear submarines, and the redirection of former weapon scientists, in the former Soviet Union countries. Later the term "engagement" of scientists substituted "redirection", and the geographical focus expanded. This shift began in 2008 and was strengthened at the G8 L'Aquila Summit in 2009

[217] Notable examples of involvement of scientists in security discussions during the Cold War include international gatherings of scientists such as the Pugwash Conferences on Science and World Affairs (Pugwash, 2013).

[218] The International Science Centres are another important example of CBRN security policies targeting the "human factor of proliferation" between the 1990s and 2000s, both for mitigating potential CBRN risk sources and for and co-optimizing technological solutions to CBRN security challenges. The International Science and Technology Center (ISTC) in Moscow and the Science and Technology Center in Ukraine (STCU) in Kiev were established in the 1990s as international organizations partnering former Soviet Union countries, Canada, the EU, Japan, the US and the Republic of Korea, and addressing the "human dimension" of CBRN risks.

(G8, 2009).[219] The rationale of the shift from "redirection" to "engagement" was that recipients of initiatives should no longer be just those with military-grade knowledge, but also those employed in civilian activities that could, on the one hand, represent a potential dual-use risk, or sources of accidental harm and, on the other hand, be important allies and sources of technological solutions for security challenges.

Other intergovernmental projects promoted the engagement of science communities, as well as international science collaboration, to directly or collaterally pursue CBRN security objectives.[220] The program by the WHO on global health security includes scientists engagement in the intersection of health and security (WHO, 2010). In the nuclear and chemical fields, international governmental organizations inserted engagement of scientific communities into the security discourse.[221] Besides governments, also national

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[219] Where "scientists engagement" was recognized a full status of security-improving tool, being mentioned in the title of a document which outlined policies to prevent WMD, the Recommendations for a Coordinated Approach in the Field of Global Weapons of Mass Destruction Knowledge Proliferation and Scientist Engagement.

[220] One example of a regional project is the establishment of the International Centre for Synchrotron-Light for Experimental Science and Applications in the Middle East (SESAME). SESAME was created under the auspices of UNESCO in 2002, and it is located in Jordan. The founding members are Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Authority, and Turkey. Another, also regional, example, is the Brazilian-Argentinian Agency for Accounting and Control of Nuclear Material (ABACC) that verifies the peaceful use of nuclear material, including the development and implementation of technological verification and control measures.

[221] Chemistry scientific communities have partnered with governmental organizations at the international level on the specific issue of education. The International Union of Pure and Applied Chemistry (IUPAC) for example partnered with the OPCW after its leadership recommended that the Union should promote education and outreach to the scientific and technical communities to increase their awareness on the CWC. A workshop organized by the scientific organization in 2005 identified target audiences for education among the chemistry community, contents, roles and responsibilities. The Union partnered with the OPCW in the project on Multiple Uses of Chemicals, which created and promoted educational materials and resources for instructors at the secondary and tertiary levels, as well as on the subject of codes of conduct (Hay, 2007). The OPCW itself become involved in the discussion of education and outreach as the Scientific Advisory Board (SAB) established a Temporary Working Groups (TWG) on analysing the issue of education and outreach on the problem of chemical weapons. According to the OPCW, education and outreach efforts should also target the public at large, but the priority is the engagement of scientists. As the TWG recommended in a report, "the OPCW should promote education and scientist engagement through professional societies, such as the International Union of Pure and Applied Chemistry (IUPAC). Education and outreach should be seen as an essential element of national implementation and is of the view that it will play an important role in preventing the misuse of toxic chemicals" (OPCW, 2013). The OPCW partnered with educators to bring education on security issues in chemistry and the chemical

and international non-governmental organizations, civil society and academia interested in security issues related to science and technology have been active in establishing and promoting links between the security and the scientific communities.[222] One particular concept that has been used in relation to scientists engagement is that of Centres of Excellence (CoE). The concept of CoE turned useful as it allows including a variety of initiatives that can collectively contribute to chemical, biological and nuclear security.[223] CoE is very relevant for scientists engagement as its common denominator is seeking, with different degrees, to provide an interface between the policy and the science and technology aspects of security.[224]

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weapons problem to high school students (Schouteten, 2013). Initiatives on education on nuclear security education and nuclear security culture were also promoted by the International Atomic Energy Agency (IAEA), including creating an implementing guide for nuclear security education, and a proposed Master of Science curriculum in nuclear security (Novossiolova and Pearson, 2012). In March 2010 the IAEA organized a workshop inviting experts from academia, international organizations, and professional nuclear material management associations. At the workshop, consensus was reached on the creation of a collaboration network for higher education in nuclear security, as this was considered an important and suitable mechanism to support and promote the sustainable establishment of nuclear security education (IAEA, 2010). The resulting International Nuclear Security Education Network (INSEN) is a partnership between the IAEA and educational and research institutions to “promote excellence in nuclear security education” for young and future nuclear scientists, exchanging information, building capacity for faculty, raising awareness. The Preparatory Commission for the Comprehensive Test Ban Treaty Organization (CTBTO) in Vienna organizes conferences on the scientific and technological aspects of verifying the prohibition of nuclear tests, involving and reaching out to researchers and practitioners. The CTBTO launched the Capacity Development Initiative to train existing and new experts on the legal and technical matters of nuclear test verification.

[222] Examples of non-governmental scientists engagement initiatives include, inter alia, those of NGOs like the Civilian Research and Development Foundation, later CRDF Global, in the US and of the Landau Network Centro Volta in Italy, and of academia like the US National Academies of Science, and the British Royal Society and the University of Bradford in the UK. These initiatives promoted international scientific and technical collaboration through grants, technical resources, training and services, analysis, multidisciplinary joint research projects, collaborative production of informative materials, sharing of scientific data.

[223] In general, CoE include a system of different skills (at the national and international, legal, scientific and political levels) that should help synergies. Activities carried out by CoE may include technical measures, facilities improvement, research, capacity building, and information sharing; involve physical equipment or intangible data; be “centralized” in a building or in a virtual hub.

[224] The current major example of CoE at the international level is the EU CBRN Risk Mitigation Centres of Excellence initiative, a network connecting European institutions, EU Member States, extra-European partner countries and the United Nations; and within them, internal and external policy officials, experts, public and private, civilian and military scientists and technologists – to address the risk spectrum from natural to accidental to intentional CBRN incidents.

Scientists engagement has hence gained relevance and support within security discourses, and described as a security instrument. It has been especially described as a component of the web of prevention of BW and deliberate disease. The reasons for this may be linked with the difficulties[225] to design risk mitigation frameworks for deliberate disease risks only based on policy norms that can at the same time provide sufficient security and enable development and application of life sciences.

4.3 Education as a security tool before 2005

A component of scientists engagement increasingly mentioned in the security discourses on deliberate disease, is the education of scientists about security issues from life sciences and biotechnology. Security discourses on deliberate diseases were traditionally dominated by political discussions on biological BW focusing on material disarmament and inter-state relationships. With – at least attempted - securitization moves, education became regarded as a potential instrument to prevent non-peaceful applications (Rappert, 2007c).

Support given to education within strategies to address deliberate disease risks date back a few decades, even if details on what education should be about, who should be educated and the role of education in respect to other security measures, vary. In the BTWC context, the Second Review Conference in 1986 noted the importance of the "inclusion in textbooks and in medical, scientific and military education programmes of information dealing with the prohibition of microbial or other biological agents or toxins and the provisions of the Geneva Protocol" (BTWC, 1986 p. 4).[226]

Scientific and academic institutions also raised the importance of awareness among life sciences, biotechnology and public health communities, rather indirectly such as in the 1985 code of ethics of the American Society for Microbiology which committed members to "discourage any use of microbiology contrary to the meaning of human kind" (ASM, 2005), to the more explicit such as the appeal by the International Network of Engineers and Scientists for

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[225] Peculiar characteristics of the life sciences and biotechnology, as well as the needs and challenges of public health, such as unpredictable and rapid research development; wide and expanding availability; low barriers to entry; convergence of scientific field; increasingly intangible and knowledge-based potential hazards; and dual-use.

[226] The note was repeated with slightly different wording in the Final Documents of the Third and Fourth Review Conferences in 1991 and 1996 (BTWC, 1991; BTWC, 1996).

Global Responsibility (INES) (INES, 2013b). In 1999, the British Medical Association published the first edition of a report aiming to raise awareness among doctors on the risks of biological weapons, stating that they should "be prepared to recognize and respond to the use of such weapons, and to advise governments on plans and policies to minimize their effect" (British Medical Association, 1999).

The attention devoted to education increased after the failure of the BTWC verification protocol in 2001 (Rappert, 2004). Particular attention was devoted to one possible way to raise awareness, that of using codes of conduct, ethics or practice. A Green Paper by the UK (Foreign & Commonwealth Office, 2002 p. 15) suggested that a code developed by academic and professional bodies, and stating that scientists "will not conduct activities directed towards the use of micro-organisms or toxins or other biological agents for hostile purposes or in armed conflict", could strengthen the BTWC. The UN Policy Working Group on the United Nations and Terrorism issued recommendations on the production of "proposals to reinforce ethical norms, and the creation of codes of conduct for scientists, through international and national scientific societies and institutions that teach sciences or engineering skills related to weapons technologies" (United Nations, 2002 p. 14). In response to the recommendations, UNESCO developed guidelines on possible codes, while the United Nations International Centre for Genetic Engineering and Biotechnology (ICGEB) focused specifically on the life sciences and biotechnology, drafting parts of a Code of Conduct for Scientists in Relation to the Safe and Ethical Use of Biological Sciences (Ripandelli, 2005).

The subject was gaining relevance also outside governments. The World Medical Association adopted a Declaration on Biological Weapons urging "all who participate in biomedical research to consider the implications and possible applications of their work" (World Medical Association, 2002). The International Committee of the Red Cross issued an appeal[227] "on the potentially dangerous developments in biotechnology" (ICRC, 2003).[228] The securitization arguments

[227] Directed to "the political and military authorities and to the scientific and medical communities, industry and civil society".

[228] The Appeal mentioned codes as awareness raising tool, and calling on political authorities to encourage their development by scientific and medical associations and by industry, and to scientific and medical communities and pharmaceutical industries to adopt them.

are straightforward, as “if biotechnology is put to hostile uses, including to spread terror, the human species faces great danger”, suggesting a consideration of the potential for deliberate disease as an existential threat for the humankind.[229]

The same year, the resumed BTWC Review Conference established the ISP of topics for meetings up to 2006, including “consideration of the content, promulgation, and adoption of codes of conduct for scientists” for 2005. However, already in the meetings in 2003 education had been underlined by States Parties. In this case, targets of proposed education were mainly officials and employees in national authorities or law enforcement agencies, rather than the scientific, medical, professional or academic communities. However there were also broader references to, for example, “all those working with biological agents and toxins” (BTWC, 2003a p. 116, statement by Poland), “specific facilities” (BTWC, 2003a p. 26, statement by the United States), “personnel working in laboratories and industries” (BTWC, 2003a p. 125, statement by the Republic of Korea). Proposed content of education would include “elements under a comprehensive legal framework” (BTWC, 2003a p. 87, statement by Australia), “biosecurity culture”, and “prohibitions of the Convention”; but in general it regarded laboratory biosecurity components (BTWC, 2003a p. 116, additional comments by the Chairman). The intended audience of these statements were primarily fellow States Parties of the Convention, and though they could be described as securitization speech acts, [230] they didn’t characterize education as urgent or responding to an existential threat – rather as a “useful”, “complementary”, “best” practice for the national implementation of the Convention.

In 2003, civil society groups interested in biological security issued recommendations for a code of conduct for scientists working in national biodefence programs (Rosenberg, 2003). In the run-up to the BTWC 2005 meetings on codes, calls on this education measure multiplied. In the UK there was particular attention, with the Foreign Affairs Committee of the House of

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[229] Certainly the appeal adopts an urgency language, including expressions such as “essential”, “before it is too late”, “taboo”, and “barbaric”.

[230] As they described education within a range of measures to improve implementation and enforcement of a weapons treaty.

Commons recommending that “the Government take steps to promulgate an international code of conduct for scientists working with dangerous pathogens, even before the BTWC considers this matter in 2005” (House of Commons, 2002).[231] The Wellcome Trust, a biomedical research funder based in the UK, considered that members of the international scientific community should be “aware of potential risks and concerns relating to terrorist misuse of research, and of the regulatory and ethical responsibilities that they hold” (Wellcome Trust, 2003). Feedback from the academic and scientific communities however, suggested a broader consideration of safety, security and ethical issues in science and technology than just focusing on the life sciences, and a more enforceable approach rather than an ethical one (Rappert, 2009).[232] Opinions suggested the primary reason for scientists becoming interested in engagements on deliberate disease risks discussions was more of avoiding regulation rather than participating in a mutually beneficial endeavour: “if scientists can’t take a few steps to police themselves, others will have to do it for them – and make a mess of it” (New Scientist, 2003), in a sort of alternative securitization move where the referent object is science, and the threat is excessive or unduly restriction. In parallel, research publishers issued a statement through the Journal Editors and Authors Group recognizing that “an editor may conclude that the potential harm of publication outweighs the potential social benefit” (Journal Editors and Authors Group, 2003).

In 2004, the report *Biotechnology Research in an Age of Terrorism* advanced the argument that biotechnologies “could also be used to create the next generation of biological weapons” causing harm “potentially on a catastrophic scale”. The very first recommendation of the report, directed to professional societies, academia, the government and scientists in general was “Educating the Scientific Community”, creating “programs to educate scientists about the nature of the dual-use dilemma in biotechnology and their responsibilities to mitigate its risks”, in order to minimize the possibility that scientific knowledge would further biological weapons or bioterrorism (National Research Council,

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[231] The UK government would go on organizing meetings and engagement occasions with scientists to discuss codes, primarily in partnership with the Royal Society.

[232] Importantly, as accounted by Rappert in his ethnography of the process of discussing and advocating for codes on preventing biological weapons (Rappert, 2009), the issue did hit the radars of parts of the scientific community, but there was not really an universal support on the idea of codes.

2004). In 2005, a group of over 60 academies of sciences around the world, the InterAcademy Panel on International Issues, issued a statement on biosecurity which included that "scientists should be aware of, disseminate, and teach national and international laws and regulations, as well as policies aimed at preventing the misuse of biological research" (IAP, 2005).

4.4 Education as a security tool 2005-2008

Meetings of the BTWC in 2005 extensively debated codes of conduct, with the ambitious objective of promoting an international code for scientists related to the prohibition of biological weapons and the relevance of deliberate disease risks. The idea of such an international code proved problematic, but nonetheless some useful debate occurred among States Parties on what codes are, who should be their promoters, what functions they would have as deliberate disease risks mitigation tools, and what limits would they have. As the pre-2005 discussion between policy and science representatives demonstrates, the "codes" rubric can be interpreted differently. Codes could be categorized as aspirational (or codes of ethics), stating ideals and ethical standards; educational (or codes of conduct) providing guidelines on roles and responsibilities; and enforceable (or codes of practice) describing required procedures (Rappert, 2004).

Consensus seemed to be widespread on that the main objective of codes would be to raise awareness, as the UK stated "promulgation of a code would involve raising awareness of the existence of the code; clarifying content and assuaging concerns; publishing information; encouraging ownership within the scientific community; establishing expectations and objectives related to adoption by appropriate bodies" (UK, 2005). Suggestions include that a code of ethics or conduct for biologists and biotechnologists should be inspired by already existing similar ones (Russian Federation, 2005b; 2005a), something also underlined by academia (Revill and Dando, 2006).[233]

[233] As identified by the ISU in its Background Paper on codes (BTWC, 2005a), a number of professional and scientific associations already possessed codes that included mentions of biological weapons and could be used as examples, such as "opposing the use of biotechnology to develop or produce any biological or other weapon" (AusBiotech, 2005); "we support the Biological Weapons Convention banning development and use of biological weapons and will not undertake any research or other activities intended for use in developing, testing or producing such weapons" (EuropaBio, 2016), also reprised and translated by national associates such as the Italian ASSOBIOTEC (ASSOBIOTEC, 2013).

A general understanding however was that no code for scientists should be developed by a security policy intergovernmental forum like the BTWC, as the Meeting of States Parties indicated that professional or academic organizations should take the lead (BTWC, 2005b).[234] States Parties basically declared themselves interested but not competent on codes. Potential weaknesses of codes were also voiced; interestingly these often related to the relationship with "hard" norms, i.e. binding regulations and legislation that are the traditional realm of government authorities. Canada provided a summary of what were seen as weaknesses of codes as instruments to support security objectives.[235]

Considerations on codes were also included in securitizing moves from the civil society. Dando and Rappert's (2005) discourse, addressed to the BTWC States Parties as the audience called for action,[236] moved from the argument that "large sections of the worldwide life sciences community have hardly begun to address the question of their responsibilities in regard to the dual-use potential of the results and techniques of their work" to require that measures "in the form of codes should be carefully examined". At the same time, they also noted that if States Parties were expecting to delegate the implementation of codes back to scientists, "a significant awareness-raising exercise" including "educational provisions" would be needed for codes. Scientists were instead the primary intended audience of Somerville and Atlas' (2005) call for "adoption of a code of ethics to govern research in the life sciences" as the necessary way to secure advances in molecular biology (the referent object) because of the "possibility

[234] The challenge of establishing international codes was also underlined in light of the geographical, cultural and technological differences, which apparently were considered stronger than the "global language of science" on this matter.

[235] First, they can be interpreted as "replacement for legislation", relaxing the pressure on the need for appropriate national legislation; on the other hand, they could contribute to an overload of lower-than-laws rules and regulations imposed by government, resulting in wasted time by scientists or to being disregarded; third, idealistic codes could create false expectations that can be difficult to keep; fourth, they could create a "chilling effect" contributing to excessive concern and paranoia around life sciences, biotechnology and public health; fifth, they could create "negative economic" incentives for people to break a (non enforced) rule, if supply of skills is limited by a code; and finally, there is a challenges to define good practices and indeed ethics as they are strongly dependent on societal and cultural contexts (Canada, 2005).

[236] As it was presented, "this Briefing Paper, with the specific purpose of assisting the deliberations in Geneva by States Parties in 2005…"

that an act of terrorism could involve biological agents" (the securitization argument).

It seemed that codes would not be an instrument to prevent deliberate disease per se, but rather that their main scope would be raising awareness: awareness is the actual security instrument. The main criticism regarded the effectiveness of codes as an awareness raising tool, and commentators underlined that the scope of codes is flawed if they are not promoted and publicized among those who should be aware of the problem (BTWC, 2005b; Revill and Dando, 2006; Rappert, 2007b).

In this regard, already during the 2005 BTWC meetings on codes other options for education were underlined. Germany suggested that codes "can only be applied if the scientist engaging in biomedical and bioscience research is aware of the dual-use problem and is well informed about ethical decision-making processes" and that "governments should therefore encourage universities to place such instruction into their biomedical and bioscience curricula as required courses" (Germany, 2005). Russia suggested "supplementing the textbooks and curricula of higher education medical, chemical and biological institutes with a lecture course on the subject" (Russian Federation, 2005b); while India suggested "training programmes and materials for educating scientists on biosafety and biosecurity issues" (India, 2005). The BTWC Sixth Review Conference in 2006 recognized "the importance of codes of conduct", and called upon States Parties "to support and encourage their development, promulgation and adoption"; however, the Conference also urged States Parties to "promote the development of training and education programmes for those granted access to biological agents and toxins relevant to the Convention" (BTWC, 2006). It also decided that one of the topics for the 2007-2010 ISP would be "oversight, education, awareness raising, and adoption and/or development of codes of conduct with the aim of preventing misuse in the context of advances in bio-science and bio-technology research with the potential of use for purposes prohibited by the Convention", to be addressed in 2008.

Calls about education (sometimes mentioning the technical aspects, others on the ethical ones) grew in the following couple of years. From the intergovernmental side, the WHO Laboratory Biosecurity Guidance mentioned that responsibilities of laboratory directors included the promotion of "a culture of awareness, shared sense of responsibility, ethics, and respect of codes of conduct within the international life science community" (WHO, 2006 p. 30). The WHO focused on awareness of workforce, suggesting that "training should help understand the need for protection", "the rationale for the laboratory biosecurity adopted", and should "provide guidance on the implementation of codes of conduct". The OECD mentioned staff training, suggesting it should develop a "biosecurity-conscious culture" (OECD, 2007).[237] The European Commission went further in a Green Paper by the Directorate-General in charge of internal security addressing, inter alia, education for students and considering that it could be made mandatory: "compulsory academic courses in life sciences could focus on dual-use consequences of bioresearch and on ethics of bioresearch. The courses could cover issues such as the risks of misuse of research results in relation to biological terrorism and warfare and professional responsibility as well as liability" (European Commission, 2007 p. 13). A similar approach was suggested in the US by the NSABB, recommending, "awareness will be enhanced through ongoing, mandatory education about dual-use research issues and policies" (NSABB, 2007 p. 9).

The 2006 report on *Globalization, Biosecurity and the Future of the Life Sciences* by the US National Academies argued that "there is a potential dark side to the advancing power and global spread" of biotechnologies, and they "may enable the development of a new generation of biological threats over the next five to ten years" (National Research Council, 2006 p. 2). To lower the likelihood of this risk, the Committee called for actions including "adoption and promotion of a common culture of awareness and a shared sense of responsibility within the global community of life scientists" (National Research Council, 2006 p. 10).[238] A Code of Conduct for Biosecurity was developed and published in 2007 by the Royal Netherlands Academy of Arts and Sciences at the request of the Dutch Ministry of Education, Culture and Science (Netherlands, 2008). The Code included the provision for raising awareness

[237] The OECD also created a website to collect and provide information on national and international activities, www.biosecuritycodes.org, which is not active anymore.

[238] Codes of ethics and conduct were regarded as a potentially useful option to achieve awareness, but they "could generally be expected to achieve their desired effect only when reinforced by a substantial educational effort" (National Research Council, 2006 p. 11).

through higher education and professional training and suggested topics for inclusion in education such as the “risks of misuse of biological, biomedical, biotechnological and other life sciences research and the constraints imposed by the BTWC and other regulations in that context” (Royal Dutch Academy of Sciences, 2007 p. 11). Reports from the University of Bradford reinforced civil society’s securitization moves. One focused on synthetic biology, where just a “brief look” would “illustrate the quantum leap in biological warfare or bioterrorist capabilities”, urging “systematic and sustained efforts at awareness raising and involving synthetic biology practitioners in the biosecurity” (Kelle, 2007b p. 3). Another report described education as a means for “in-depth implementation of the BTWC” and, justified by the “great need for education and outreach to raise awareness amongst the life science community”, called upon BTWC States Parties to incorporate codes of conduct into the Final Declaration of the Review Conference (Rappert et al., 2006). In 2008 the US Congress-mandated Commission on the Prevention of WMD Proliferation and Terrorism contributed powerfully to the securitization discourse regarding bioterrorism. The report noted that “unless the world community acts decisively and with great urgency, it is more likely than not that a weapon of mass destruction will be used in a terrorist attack somewhere in the world by the end of 2013”, and “that terrorists are more likely to be able to obtain and use a biological weapon than a nuclear weapon”; from these premises, they addressed the scientific community arguing that it could “wait until a catastrophic attack occurs before it steps up to its security responsibilities. Or it can act proactively in its own enlightened self-interest, aware that the reaction of the political system to a major bioterrorist event would likely be extreme and even draconian, resulting in significant harm to the scientific enterprise” (Commission on the Prevention of Weapons of Mass Destruction Proliferation and Terrorism et al., 2008 pp. xv, 26).

In the BTWC context, meetings in 2008 discussed experiences, approaches, formats, audiences and concerns of oversight, education, awareness raising and codes. Considerations included that bottom-up (self-regulatory, non-governmental) approaches are “better tailored to the demands of the community, are self-sustaining, more easily harmonized, and can be more comprehensive” (BTWC, 2008a p. 32, statement by Brazil). Some States Parties however were not convinced that a bottom-up approach alone would promote effective education, as Ukraine noted, “there is still very limited awareness of the

Convention amongst life scientists. Indeed, the awareness of life scientists is such that they cannot be expected to spontaneously initiate a ‘bottom up’ approach to the development and implementation of codes of conduct” (Ukraine, 2008).[239] Japan posited that “programs for education and awareness raising among scientists are a basic means for preventing the misuse of biotechnology”, as “even well-intended research could bring about harmful results through is misuse” and suggested that targets of education should include students in universities and secondary schools, and researchers at universities, institution and industry as well as health care workers (Japan, 2008).[240] Ukraine (2008) identified biotechnology and synthetic biology as the referent objects for its security discourse on education, justified as “misuse of these developments intentional or nonintentional may create biological threats, which are difficult to predict but necessary to overcome”, and urged to “foster the development and implementation of codes of conduct and educational processes.” Statements along similar lines were delivered by Kenya (Kenya, 2008), Korea (Republic of Korea, 2008), Iran (Iran, 2008), Morocco (Morocco, 2008), Pakistan (Pakistan, 2008a) and Russia (Russian Federation, 2008). Regarding contents, it was noted how education should include ethics, information on dual-use risks, the management of sensitive information, and legal obligations from both international treaties and national legislation (Japan, 2008), as well as biosafety and biosecurity (BTWC, 2008a p. 27, statement by the US National Academies of Science). Certainly there were recognitions that the subject would be interdisciplinary, requiring contributions from experts from a range of fields such as government, academia, industry, civil society, social science and ethics (UK, 2008; Pakistan, 2008b). During the meeting however, some States Parties also expressed concerns on education (in particular regarding dual-use) as an instrument to mitigate deliberate disease risks, that could be summarized in the danger of regulations depriving some States of the benefits of research for peaceful purposes (BTWC, 2008a pp. 26–27, statement by Brazil; Nigeria, 2008; Pakistan, 2008b; Cuba (on behalf of NAM), 2008). From the civil society, States Parties were invited to “actively promote and fund collaborations” on education for those associated with the life sciences (Lentzos and Sims, 2008)

[239] Regarding audiences, both pre-service education and in-service training were underlined.

[240] The value of starting education on security issues at an early stage, during the scientific formation, to reach researchers and scientists of the future, was also reiterated by the Netherlands (2008).

and to include in their report that “all those graduating from higher education in fields associated with the life sciences should be familiar with the international prohibition against biological weapons”, *inter alia* (Rappert, 2008).

The Report of the 2008 BTWC Meetings invited States Parties to the Convention to “develop, implement and support education and awareness-raising programmes that:

i) Involve, and are developed in collaboration with, all relevant stakeholders from both public and private institutions and associations, as well as managers and administrators of universities, research institutions and commercial companies, and individual scientists;
ii) Explain the risks associated with the malign use of the biological sciences and biotechnology and the moral and ethical obligations incumbent on those using the biological sciences;
iii) Provide guidance on the types of activities which could be contrary to the aims of the Convention and relevant national and international laws and regulations, including on the export and import of biological resources;
iv) Are tailored to the target audiences as not all stakeholders need to receive the same message”.

The Report went on recommending that States Parties:

i) “Establish formal requirements in relevant scientific and engineering training programmes and continuing professional education, such as mandatory seminars, modules or courses;
ii) Create accessible teaching materials which address the Convention, relevant national laws and guidelines, and related issues […]”.

Importantly, the second group of recommendations were indicated as “depending on national circumstances”, so that each country would have to consider who should implement them, and how (BTWC, 2008b pp. 14–15).

4.5 Education as a security tool 2009-2015

After 2008, calls on the importance of education as a security instrument further evolved and expanded to new constituencies. Among intergovernmental organizations, the EU kept the point on education and awareness raising in its EU CBRN Action Plan, which contained the recommendations for improving

CBRN security within the Union.[241] One of the actions in the plan stated that "the Member States and the Commission should consider and develop:

- Guidelines at the EU level for minimum training requirements for persons working with, having access to, substances on the EU list of high-risk biological agents and toxins;
- In conjunction with universities and professional associations, minimal requirements for academic training on biosafety, potential misuse of information and biological agents and toxins and bio-ethics for undergraduate, graduate and postgraduate students". (Council of the European Union, 2009 p. 74; European Commission, 2009).

The G8GP looked to education as a non-traditional instrument to combating WMD, as countries should support, inter alia, the "development and adoption of codes of conduct and awareness raising tools in the scientific education at the national level" (G8, 2009). This was reiterated in 2011 (G8, 2011) and 2013.[242] The WHO published a guidance document on *Responsible Life Science Research for Global Health Security*, stating that "a culture of scientific integrity and excellence, distinguished by openness, honesty, accountability and responsibility" would be the "best protection against the possibility of accidents and deliberate misuse, and the best guarantee of scientific progress and development". The report encouraged countries and institutions to invest in "training personnel (laboratory staff and researchers) and students in ethics, the responsible conduct of research, and biosafety and laboratory biosecurity" (WHO, 2010 pp. 1–2).

Members of the civil society continued arguing that lack of awareness among life scientists would raise the "dual-use risk of proliferation of knowledge, materials and equipment" (Shinomiya, 2009) and urged that the BTWC adopted a plan "that includes as an essential integral element the requirement to carry

[241] Furthermore, the EU Joint Action in support of the BTWC included among "concrete measures to enhance the effectiveness in the implementation of the WMD strategy" the promotion of "bio-risk reduction practices and awareness, including bio-safety, bio-security, bio-ethics" (Sweden (on behalf of the European Union), 2009).

[242] "Long term sustained efforts [are] needed across broad range of scientific and engineering disciplines, including promotion of education and awareness raising on dual use issues, biosecurity, biosafety and importance of the BTWC. There is a need to include social scientists and ethicists here too" (Foreign & Commonwealth Office, 2013 p. 9).

out such an education and awareness programme” (Whitby and Dando, 2010b). Consideration evolved also in the professional private sector, as suggested by the Code of Conduct issued by the International Association of Synthetic Biology (IASB) including extensive considerations on security risks (IASB, 2009); the suggestion by the German association for the life sciences that even undergraduate students should at least know the biorisk management legal bases (Verband Biologies, Biowissenschaften und Biomedizin, 2010); or the internal training implemented by pharmaceutical companies such as AstraZeneca (AstraZeneca, 2014).

In 2010 the US National Academies published the report *Challenges and Opportunities for Education About Dual use Issues in the Life Sciences*, which identified higher education as the most appropriate context to implement education; ethics and responsible conduct of research as the best existing channels in that context to incorporate education; and dual-use as the most appropriate focus to introduce education on deliberate disease risks using those channels. The report also identified challenges in lack of educational resources; the need for better use of science of learning and effective teaching; and crowded curricula and lack of support for teaching compared to research in graduate education. Recommended actions included the establishment of an international repository of educational materials on dual-use issues; collaborative production, commenting and vetting of materials; building networks of faculty and educators; and developing methods to assess outcomes of education on deliberate disease risks (National Research Council, 2010).

The 2011 BTWC Seventh Review Conference placed emphasis on education as a long-term way to implement the provision of the Convention. A group of States Parties reported their national experiences and recommendations in a Working Paper (Australia et al., 2011), underlining “that the frequent lack of awareness of aspects related to biosecurity and the obligations of the Convention among life scientists has to be addressed more urgently, strategically, and comprehensively”; and highlighted that decisions on the “form and nature” should be taken at the level of each State Party. The group proposed that States Parties inform on their awareness raising activities, possibly using existing CBMs forms, and that the ISP before the Eighth Review

Conference in 2016 considers more in detail education and awareness raising. The Final Declaration of the Seventh Review Conference reflected some of these recommendations. Regarding Article IV, the Conference noted the value of, inter alia:

c) “encouraging the consideration of development of appropriate arrangements to provide awareness among relevant professionals in the private and public sectors and throughout relevant scientific and administrative activities, and

d) promote the development of training and education programmes for those granted access to biological agents and toxins relevant to the Convention and for those with the knowledge or capacity to modify such agents and toxins”.

The Conference included education transversally among the three Standing Agenda Items (SAIs) for the ISP 2012-2015. The first SAI on cooperation and assistance included as one of its points:

a) “education, training, exchange and twinning programmes and other means of developing human resources in the biological sciences and technology relevant to the implementation of the Convention, particularly in developing countries”,

whereas the SAI on review of developments in the field of science and technology related to the Convention included:

d) “voluntary codes of conduct and other measures to encourage responsible conduct by scientists, academia and industry;

e) education and awareness raising about risks and benefits of life sciences and biotechnology.”

And the SAI on national implementation, while not explicitly mentioning education and awareness raising measures, included:

e) “any potential further measures, as appropriate, relevant for implementation of the Convention” (BTWC, 2012a pp. 11, 22, 23, 24).

Indeed subsequent BTWC meetings confirmed that education was at that point acknowledged as part of national implementation of the Convention. Poland stressed that “there is a need to enhance awareness […] to minimize the risk that life sciences products or knowledge may be misused or misapplied toward malevolent goals” and recommended that the Meeting agreed on “steps to be taken nationally to ensure that biosafety, biosecurity and the prohibitions and obligations of the Convention are included within the provisions for education of all life scientists" and on reporting on initiatives taken "so that the experience gained and best practices can be shared for the benefit of all States Parties" (Poland, 2012 p. 2). Other States Parties made recommendations on similar lines (Canada, 2012; Chile et al., 2012; Benin, 2013). Education even became a potential tool of compliance assurance with the provisions of the BTWC, as Japan (Japan, 2013 p. 2) stated "education and awareness-raising for scientists could also be a means to prove compliance on BWC" and the UK (UK, 2013 p. 7) included among "actions and activities indicative of compliance", "sustained measures to promote awareness of the Convention and its requirements in the scientific community and to promote a culture of responsibility".

The idea of integrating education on deliberate disease risks in university curricula (Kenya, 2014; India, 2015), and in "an early stage" (Netherlands, 2015), became increasingly salient. Austria (Austria, 2015 p. 2) explicitly included the "integration of biosafety and biosecurity into university curricula" as one of the measures of scientists engagement to manage "risks immanent in the ongoing advancement of the life sciences and biotechnology". The German Ethics Council noted a need to introduce "a teaching module on the topics of dual-use and biosecurity into graduate studies" (Deutscher Ethikrat, 2014 p. 158).

Civil society strengthened the securitization effort,[243] evaluating that progress on education "has been slow demonstrating the need for consolidated efforts and long-term commitment". States were called to enact internationally coordinated efforts, educational requirements and standards mandated by governments, adequate funding, and reporting to BTWC meetings (Novossiolova, 2013; Switzerland, 2013; INES, 2013a). The very first recommendation of the Royal Society report on Neuroscience, Conflict and Security in 2012 called on "appropriate professional bodies to inculcate the awareness of the dual-use challenge […] among neuroscientists at an early stage of their training" (Royal Society, 2012 p. 60). A 2014 report from the InterAcademy panel focusing on opportunities and governance of synthetic

[243] And reinforced the securitization message that technology "pose an unprecedented challenge to the integrity of the international prohibition of biological weapons" (Novossiolova and Pearson, 2012 p. 17).

biology had as first recommendation "preparing researchers for work in synthetic biology", including preparing "the next generation of skilled researchers" through the incorporation of "collective learning about the relevant ethical and social issues" that should "embrace the social sciences and humanities" in an interdisciplinary approach (IAP, 2014 p. 2).

4.6 Analysis of securitization moves

As the above overview illustrated, a range of attempted securitization moves pushed education into the security toolbox to mitigate the risks of deliberate disease. These moves involved a number of securitizing actors, intended audiences, identified referent objects, arguments and proposed measures, and had various degrees of audience acceptance and of implementation to determine actual and successful securitization.

4.6.1 Securitizing actors, audiences, referent objects

Securitizing actors came from two main groups: governmental actors and civil society. The first group included States acting within and beyond the BTWC context as well as intergovernmental organizations and groups such as the WHO, the OECD and the G8. Within civil society, securitization speeches came from both those interested in, and with a background of, security, such as disarmament groups and academia; and from the scientific community such as professional associations, research institutions and publishers. Securitization messages were mainly directed at two intended audiences: States and the scientific community. Within the latter, different representatives were addressed by different securitization discourses, from the individual scientists to organizations of scientists or universities and other HEIs. Finally the referent object of securitization moves varied, being however always related to the life sciences and technologies.[244]

4.6.2 Discursive devices

Security terminology and language, applied to express the sense of urgency and emergency in face of threats, is recognizable when looking at the arguments brought in securitization speeches to justify proposed security

[244] While some statements mentioned generally biotechnology, some identified more specific fields of attention such as molecular biology, genetics, or fields converging with chemistry like neuroscience. Synthetic biology received particular attention as a referent object, as did "advancements" in science that arguably, according to proposers of security measures, pose heightened risks than "old" ones. Some speeches focused on both or either (material) "products" or "knowledge" of the life sciences.

measures.[245] The two main arguments were firstly the potential misuse of life sciences and technologies, a risk depicted as both likely[246] and with destructive potential; and secondly the lack of awareness among scientists. Clearly the sense of urgency, the evaluation of the risk, the essentiality of education as a security measure, and the anticipation of dangers should the measures not be accepted, vary among different securitizing actors.[247] Uses of discursive devices can be recognized in these securitization speeches. It's noteworthy as security proponents aspired to publish articles on life sciences and technologies journals such as Science Magazine (Somerville and Atlas, 2005), Nature (Dando, 2009a) or the EMBO Reports (Revill and Dando, 2006). This was not only to easily reach life scientists, who arguably are the primary readers of those publications, as respected generalist mass media would also work in that sense. It is also to respect the *partages* (using terminology identifying the boundaries of a subject matter), the *discipline* that may help considering uttered propositions as "true", and the complex of the *will of truth* accepted within the population of life scientists.[248] Another discursive device almost systematically used – primarily by civil society, but also by States – is the resort to the *commentary* or stressing the *author*. It was common that, between securitization arguments and proposed security measures, securitization statements reported quotes from sources supporting similar moves (Dando and Rappert, 2005; National Research Council, 2010). Several statements extensively quoted the very same audience they were directed to, almost to remind them of what themselves had uttered, recommended or committed on before, resorting to positive (coherence in the audience with what they had supported) and negative (wouldn't the audience be in an uncomfortable position if not accepting these measures appeared inconsistent with their previous positions?) reinforcements

[245] It's interesting to note instances when statements drafted education as a weapon in the war against deliberate disease already from the title, such as in "*Ethics: A Weapon to Counter Bioterrorism*" (Somerville and Atlas, 2005)

[246] "Every major technology has been intensively exploited" (Meselson, 2001 p. 1); "as with all scientific revolutions there is a potential dark side" (National Research Council, 2006 p. 2); "information may be found on the internet" (Japan, 2008 p. 1).

[247] States – particularly in the BTWC context – used softer tones in their recommendation compared to civil society, often resorting to formulae such as "should", "has the potential to be useful", "can help", etc.

[248] Ultimately, it's the desire of security proponents of exploiting the aura of scientific truth and respect attributed by the audience to the journals, to help have their securitization moves accepted.

(Rappert et al., 2006; Whitby and Dando, 2010b; Novossiolova and Pearson, 2012; INES, 2013a; Novossiolova et al., 2013; Novossiolova, 2015).

4.6.3 Measures proposed by securitization moves

In order to evaluate the acceptance and success of securitization moves – i.e. the actual implementation and institutionalization of proposed measures, it is useful to categorize the measures advanced by the acts described in previous paragraphs. We can recognize six main actions addressed to States:

- Recognize the value of education as a risk mitigation measure in security venues;
- Regard education as a necessary component of national implementation of, and compliance with, the BTWC;
- Report and share on national efforts on education as a security tool against deliberate disease;
- Work to promote education with organizations at the national level, especially professional associations and Ministries competent for education;
- Develop national and international action plans on education, including goals, objectives, milestones, funding, and assessment methods;
- Fund initiatives and projects on education to counter the risk of deliberate disease.

And three main actions called upon scientific communities:

- Be aware and recognize the relevance of the risks of deliberate disease;
- Develop and implement educational initiatives and materials;
- Integrate education on deliberate disease in higher education national systems for scientists.

4.7 Implementation of securitization moves addressed to states

Regarding the first measure urged on States, the move was successful in that the salience of education steadily increased between the early 2000s and 2015 in consensus statements of governmental security venues (BTWC, 2005c; BTWC, 2008b; G8, 2009). Education became particularly recognized during the second BTWC ISP, being an explicit SAI sub-item and constantly reinforced in Meetings Reports (BTWC, 2012b; BTWC, 2013; BTWC, 2014). Education is something that everyone in the biological security governmental community seems to accept as an instrument to mitigate deliberate disease risks, even those organizations that had previously resisted being securitizing actors of public health (Kelle, 2005c). The consensus acceptance on education as a security instrument may also be an example of what Kelle calls "institutionalization of a lower level" (Kelle, 2005c p. 36), easier to accept as less binding for States than harder security commitments.

The call to States to consider education as part of national implementation of the obligations of the BTWC, or even as a measure of compliance to the Convention, had a mixed success. Educational initiatives became often reported under national implementation as well as described as covered by Article IV. However, educational initiatives were not systematically included in national implementation measures, BTWC Review Conferences did not expand CBMs to explicitly mention education, and no consequence for insufficient implementation or non-compliance are foreseen for States that do not act on education. During the second BTWC ISP, the SAI including education was review of science and technology advancements, not national implementation. So, while some States clearly consider education as implementation of the Convention, and no State clearly opposes such a view, by no means the whole audience took action on this basis.

Regarding reporting to the BTWC on education efforts, so that others can learn and take advantage of previous experiences, the move was generally, but not completely, successful. Reports (often in the form of co-authored Working Papers) collected national experiences, and presentations in Geneva on education multiplied. However, the Sixth and Seventh Review Conferences did not formalize any requirement on reporting education in the BTWC.

The call to governmental bodies traditionally involved in security issues (such as Ministries of Defence, Ministries of Foreign Affairs, or law enforcement agencies) to work at the national level with organizations competent on designing and mandating scientific education such as professional associations, Ministries of Education, universities boards, and professional-credits awarding agencies, had a mixed success largely depending on national systems. Certainly examples such as the work in the US by the FBI with universities (Lempinen, 2011; AAAS, 2013) suggest that the utterance was accepted, however in many other countries national security actors diverted the duty to the science education community itself.

One of the most called upon measures between 2005-2015 was the development and approval by States of national and international plans on education including goals, objectives, milestones, funding and impact assessment measures. This was not implemented as notwithstanding States' recognition, they largely continued collecting and reporting initiatives led by other organizations, or supporting individual projects.

Funding was something where securitization moves have been quite successful, as a trend can be observed in the plethora of supported biological security projects and programs that increasingly included educational actions. This seems apparent, for example, from the US Department of State's Biological Engagement Program supporting, besides laboratory biorisk management, projects on bioethics and biosecurity education, to the largely training component of the EU CoE initiative consolidating all CBRN risk mitigation initiatives, which funded the creation of networks of universities to raise awareness about dual-use.

4.8 Implementation of securitization moves addressed to the scientific community

Success, or lack thereof, of calls for action directed at the scientific community is even more interesting for the purpose of this research. The urge on scientists to become aware and recognize the relevance of the risks of deliberate disease has gradually moved from being resisted (Dando and Rappert, 2005; Mancini and Revill, 2008) to being accepted by larger sections of the scientific community as the securitization speeches became more pervasive, though certainly is still far from widespread implementation. Scientists also attempted counter-securitization moves (Dando and Rappert, 2005) to protect science from unduly and possibly threatening regulation,[249] in a dialectic confrontation between two opposite speech acts.[250]

[249] As Rappert and Dando (2005) reported, particularly the "classic open science type" participants to the seminars used counter-securitization arguments including that "people who obey the regulations are not the people who are going to try and do, use science for these sorts of [malign] ends. So you end up actually just hurting the people who are trying to use the science for positive reasons, by putting more obstacles in the way" and "you are damning the technology just because it happens to be able to make

Some actions followed up to the calls to develop and implement educational materials, such as the Case Studies in Dual-Use Biological Research by the Federation of American Scientists (FAS, 2009) and the website on Dual Use Dilemma in Biological Research by the Southeast Regional Center of Excellence for Emerging Infections and Biodefense (SERCEB, 2010). The discussion-stimulating seminars in universities by Dando, Rappert and colleagues (Dando and Rappert, 2005) were an awareness raising effort, however not "an *efficient* method of raising awareness" (Rappert et al., 2006 p. 28, emphasis in the original) as they addressed small groups and did not assure repetition for new faculty members. One way they suggested to reach larger numbers of scientists in different countries, limiting the time and effort spent, was the development of educational modules that educators could use as a resource.[251]

One important specific measure urged by securitization speeches was the integration in relevant curricula by higher education institutions. From the experience of the seminars it seemed clear that it was "unrealistic to expect that simply adding a lecture to a standard course in the life sciences will make a great deal of difference", leading to the proposal of introducing possibly mandatory modules covering deliberate disease risks in relevant degree courses (Rappert et al., 2006).[252] An effort was also undertaken by the University of Bradford in collaboration with the National Defense Medical College in Japan and the Landau Network-Centro Volta in Italy with the preparation and publication of the Educational Module Resource (EMR).

Ebola potentially in about three or four years' time" thereby resisting measures such as pre-project or pre-publication review systems.

[250] Some areas of the scientific community may have accepted the calls for actions to a larger extent than others, as can be suggested by the IASB code being a response to calls on specific concerns from synthetic biology from both the civil society (Kelle, 2007b) and governments (European Group on Ethics in Science and New Technologies to the European Commission, 2010).

[251] Another factor is using alternative methods than lectures to deliver the seminars: they report that using role playing exercises could have been both an effective (because of the impact of learning through experience) and appropriate (given the often divisive opinions related to dual-use) approach for teaching security issues (Rappert et al., 2006).

[252] This was perceived as one possible initial step, and as can be suggested by the importance impressed by the OPCW, IUPAC and IAEA on higher education as a channel for education on security implications of chemistry and nuclear physics, maybe one of the reasons of ignorance is precisely that these issues do not feature in life sciences and biotechnology university formation (Whitby and Dando, 2010a).

Designed as a resource of educational materials for instructors, organized in lectures so that professors would not need to research and assemble materials on security and dual-use issues but only select and customize what they deem more relevant for their students, the EMR assumes a final audience of university students in life sciences, biotechnology and public health with little or no prior knowledge of biosecurity (Whitby and Dando, 2010a).[253]

Offering a comprehensive educational resource however would not ensure implementation by science educators, as the primary challenge remained the lack of priority and perceived importance in the scientific community. Other initiatives sought to address this engaging the academic community on the design and implementation of education. Within the "Fostering the Biosecurity Norm" project by the Landau Network Centro Volta and the Bradford Disarmament Research Centre, in 2009 there was a follow up to a survey on contents of degree courses in Europe and, based on the data collected and leveraging a network of life sciences and biotechnology educators engaged during the inquiry, as series of seminars were organized (Mancini and Revill, 2009). Rather than being based on a format designed by the proposers, the seminars were collaboratively prepared and organized with the local professors, often embedded during their regular courses.[254] This not only certainly contributed to a better reception by faculty and students of the topics[255] but also provided suggestions on how to frame them in a more acceptable way for the science community.[256] Questionnaires at the end of the seminars, which

[253] Contents and key messages have been included based on the recommendations of the 2008 BTWC Meeting of States Parties on education, including the history of the threat of biological weapons, the international prohibition regime, the issue of dual-use and the responsibilities of life scientists, and the web of prevention. The EMR is freely available on the web and over the years has been translated to several different languages.

[254] Professors ensured students participated but also, with their endorsement, eased the acceptance of messages on security and dual use issues by the audience. To obtain this level of engagement from local professors, authors had to compromise and modify some of the messages and contents proposed, especially on what scientists felt too strong in underlining the dangers, or understanding the likelihood, of security risks.

[255] Which, while modified in the presentation and coupled with other subjects, maintained the core messages on deliberate disease risks including the dual-use potential, that was the aim of the project.

[256] Indeed all seminars included, as a minimum, information on the history of biological weapons; dual-use; and the web of prevention, including the BTWC. The EMR was the main source of materials (lectures, discussion questions, exercises) for the seminars, while local organizers provided additional lectures making interdisciplinarity a common feature of the series.

reached nearly a hundred students in seven universities suggested that "students generally appeared to feel that the seminars improved their understanding of issues such as biosecurity, the risk posed by dual-use research, the BTWC and the history of biological weapons" and that a clear majority of students felt that "awareness raising should be promoted among students" (Revill and Mancini, 2010 p. 172).[257] The experience also suggested that networking among scientists in academia and between them and civil society organizations concerned with security issues may be a viable way to raise awareness on the relevance of the subject and promote implementation of education, as Whitby and Dando (2010b) and the US National Academies (National Research Council, 2010) noted. The experience suggested something similar to what Switzerland reported from seminars in the country: "life scientists consider awareness raising on aspects related to security as important, some even spoke of an 'eye-opener'" (Australia et al., 2011 p. 12).

In 2009, the University of Bradford developed a fully accredited online-based train-the-trainer module titled Applied Dual-Use Bioethics and Biosecurity (Sture and Minehata, 2010). The aim of the module was to introduce participants to bioethics as it relates to biosecurity, train them to integrate biosecurity issues into their teaching.[258] The University of Bradford also collaborated with the Public Health Agency of Canada to develop a university-level course for faculty members. Such an experience led Canada to consider the development of formal degree courses on biosecurity, dual-use, biosafety and bioethics (Australia et al., 2011 p. 8). Finally the University of Bradford developed a National Series of lectures focusing on the biosecurity situation of specific countries (Sture and Minehata, 2011; Espona and Dando, 2011).[259]

Enemark (2010) summarized the initiatives to close the education gap in Australia.[260] Impressions of the researchers were that almost all participants

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[257] Feedback from students underlined an interest in the topics, a demand for additional information, and the need to provide more complete and advanced modules.

[258] The module was delivered through the Elluminate software, allowing video and audio connections, group work and discussion between class members and students.

[259] This short course includes contents such as risks related to disease, including biological weapons; development of the prohibition regime on biological weapons; the dual-use dilemma and the responsibilities of life scientists; national implementation of the BTWC; and building a web of prevention.

[260] A multidisciplinary group of Australian academics, including scientists, bioethicists and political scientists, carried out seminars in 2009 adapting the model used by British colleagues.

were unaware of the existence and provisions of the BTWC, that they underlined the importance of freedom of publication and opposed increasing governmental regulations on biosecurity. However, scientists in universities seemed to start seeing the importance and the relevance of discussing the issues.

Connell and McCluskey (2010 p. 152) summarized the efforts made since the early 2000s for introducing education and guidelines to the university community in the US, identifying four avenues for implementation: the federally mandated Responsible Conduct of Research education of trainees sponsored by the National Institutes of Health; the Institutional Biosafety Committee required to review recombinant DNA and infectious agents experiments; the laboratory safety training mandated by the Occupational Safety and Health Administration for all lab workers; formal education on biodefence; and a mandatory in-service train-the-trainer path where dual-use awareness is included in periodic seminars. Also the US National Academies developed university teachers in various countries on teaching security in the framework of research ethics and responsible conduct of science, as well as on using the most effective pedagogical methods based on the science of learning (National Research Council, 2012). Sandia National Laboratories International Biological and Chemical Threat Reduction (IBCTR) Program (Sandia National Laboratories, 2014a) performs a number of projects related to biosafety and biosecurity, including education of scientists.[261]

In Japan, the National Defense Medical College in collaboration with the BDRC introduced since 2008 education on deliberate disease risks coupled with bioethics and medical ethics and including dual-use issues, for both undergraduate and graduate students. Medical students go through a two-day course on dual-use and security just before their Hippocratic Oath and graduation, while PhD students receive further three days of training. Educational materials are obtained from the EMR blended with biosafety concepts and practical activities (Sture and Minehata, 2010 p. 25). Other

[261] The Global Biorisk Management Curriculum (GBRMC) (Sandia National Laboratories, 2013) is largely focused on biorisk management in a laboratory context; it is also principally designed for the training of in-service and practicing scientists rather than young scientists and students. However, it provides trained instructors with reference materials, ready-to-use lectures, exercises and activities for students based on a facilitated learning format.

universities in Japan, such as Waseda University, Keio University, Jikei University and Tokyo University organized educational initiatives on either the safety and response to bioterrorism events or the ethical and social issues related to potential misuse, but rarely involving students from science degrees (Australia et al., 2011 p. 9).

In other countries, few individual universities developed educational programmes for their students; even if this often seemed the result of the interest of committed individuals rather than a concertized approach. At the Quaid-i-Azam University in Pakistan a course on Bioethics, Biosafety, Biosecurity and Dual-use was introduced for postgraduate students (Shinwari, 2011). At Uppsala University in Sweden, lectures on security issues have been adapted from the EMR and included into ethics courses for biotechnology students (Smallwood, 2009). In 2012 Revill et al. (2012) collected experiences, achievements and challenges from life science professors implementing education on security issues, and specifically dual-use, in Austria, Italy, Pakistan and Sweden.[262] These experiences further underlined the importance, and the potential increased acceptance by young life scientists and educators, of an interdisciplinary and holistic approach that both addresses the complex links between fields and broadens the narrow security perspective on potential misuse for terrorist purposes but blends with, for example, health and environmental security and sustainability.

The securitization calls for action upon the scientific community to develop and implement education on the risk of deliberate disease, and particularly to formally integrate it within national higher education systems for scientists, received interest and were accepted by increasing sections of the audience. While this suggests that the securitization speech act was successful, implementation has not been widespread or sustainably integrated in formal structures, as well as rarely became mandatory for science students. The lack of systematic assessment makes unclear the extent to which measures were

[262] The account from the University of Vienna showed how a laboratory biosafety course was incrementally expanded with materials on security issues and the problem of deliberate disease as one of the lecturer realized the importance of education after having participated to the work of UNMOVIC. In Italy, collaboration between interested life science professors and civil society organizations focused on security issues, led to the organization of some of the European seminar series, as well as to the recognition (CBUI, 2008; 2009) by the Italian National Board of University Biologists of the need to develop and incorporate education about foundations of dual-use issues at the various levels of the academic cursus.

implemented, and hence if the securitization move was truly successful, as well as understanding how to facilitate their implementation in future endeavours.

4.9 Constructing and assessing education as a security tool

There have been a number of experiences and initiatives to close the education gap, which could also be considered as implementation of securitization moves that called upon the scientific community. These not only functioned as awareness raising tools, but also helped to understand what worked well and what was less efficient.

Having demonstrated that raising awareness and educating the life sciences, public health and biotechnology communities on deliberate disease is feasible still leaves a number of questions open, unresolved or untested. Despite agreement among those involved in this sector that education is, at best, "patchy and ad hoc" (National Research Council, 2010 p. 64), gap analysis so far had a number of limitations. Most existing research on what educational offerings exist and what scientists already know, think and do with regard to security issues in the life sciences and technology, as well as attitudes towards the web of prevention including education, offer no quantitatively statistical representation or qualitatively deep analysis, and only a small number of them allow for comparative analysis among scientifically or culturally inhomogeneous regions. Furthermore, no structured analysis of changes over time in the same context have been performed so far, with inference being difficult comparing studies on different groups and using different methods; and this may be a key issue since the implementation of educational programs, and their impacts, may certainly be long-term ones. Finally, at this point carefully rethinking indicators may be useful to understand nuances and characteristics of awareness, since as Rappert (2010) pointed out a lower identification may either mean a lower risk or a low aware community.

Among open or untested questions there are also those of the role of education, its content, targets, where should it come from, and what are the best methods to deliver it as a web of prevention component. Rappert (2010) has collected various roles that education may be considered or auspicated to have. Among those types, I think that as a part of the web of prevention of deliberate disease risks, education should be considered: i) as a prerequisite, necessary for other security-related activities to be undertaken; b) as a deficiency correction, correcting the lack of knowledge that is deemed good and useful and; c) as guardianship, as it enables more cognizant communities to participate to relevant activities, help and scrutinize governmental actions, inform the society and reinforce the stigma against deliberate disease.

Regarding proposed contents of education, positions to date can be summarized in two main groups: those who think that the priority should be on the laboratory context and technical safety and security, and those who see in ethics and responsible conduct of research a better framework to channel the complex aspects of deliberate disease risks.[263] Experiences in universities suggested that educational materials should acknowledge the benefits of scientific research; uncover the existence of past biowarfare programmes; mention national and international prohibitions; discuss the dual-use dilemma; refer to the wider economic, social and security implications of life sciences and biotechnologies (Mancini and Revill, 2009); and discuss relevant laboratory biorisk mitigation measures. Certainly, the interdisciplinarity of the deliberate disease risks subject seems agreed by most commentators. In our opinion, decisions on contents and messages would also determine who would be the educator, i.e. who is considered entitled and expert to teach about deliberate disease risks: clearly, this may not be a single individual. However, notwithstanding efforts to customize education and calls that "no one size fits all", educational contents on deliberate disease risks still is much derived from, or targeted to, Western, and in particular American, cases and audiences, as well as largely in English (National Research Council, 2010). Furthermore, no specific analysis has been done on the construction and empirical testing of messages within the educational content.[264]

Another point is who should be educated, i.e. who is the target audience of content. Rappert (2010 p. 6) asked: "should they be pathogen investigators, bioscientists as a whole, those associated with the life sciences in general, or the public?" According to the NSABB, all of those could be target audiences, but

[263] Content would be informed by decisions on both what would be the most important risks to address (state-level biowarfare programs, bioterrorism, options opened by future technological and security developments) and what the most efficient methods of mitigation (technical, ethical, regulatory knowledge).

[264] Discussions on deliberate disease risks can be sensitive for life scientists, and ways to design, construct and deliver educational messages and programmes that are not confrontational but channel the reasons for concern have to be refined, so that the feasible partnership between the civil society interested in mitigating security risks and the scientific community is hardened.

they should be identified and their level of understanding assessed, so that specific messages could be tailored. In this research, I choose to focus on the education and awareness raising of one subgroup in the life sciences, biotechnology and public health community: that of undergraduate and graduate students in tertiary education. Reasons for this focus are both practical and functional and have been discussed in Chapter 1.[265]

In the following Chapters, the thesis will try to contribute to these points, moving from what has been advanced so far. It has been suggested, for example, that it is often difficult and/or time consuming to establish new structures or programmes in higher education, and that expanding existing relevant offerings may be a more practical and quick solution. Another issue is making education compulsory or optional; the former would enable reaching all relevant future scientists, and possibly also do that on a common programme. This approach has been proposed in the past, however it must be considered that this would not be an easy nor a short process and would have to cope with many different academic and/or governmental systems at the national levels; moreover it is likely to encounter resistance in the scientific community and to result at best in a "tick-box" approach (National Research Council, 2009b). Especially in those systems with a historical academic autonomy, an imposition of content within the curriculum, if possible at all, would be met with scepticism (Australia et al., 2011 p. 12). Commentators maintained that there may be scope for a bottom up approach, where scientists, especially in HEIs, may be engaged in the process of promotion of educational opportunities when involved in the design of education (Revill et al., 2012) using civil society networks between scientific and security communities (Whitby and Dando, 2010a). Even if this approach alone would not sustainably resolve the education gap, and even if it should be complemented by a top-down support at the national and international level (on which experience in the nuclear and chemical sectors may represent a model),

[265] Similarly to what was presented by Rappert and Dando (2005), scientists in academia are more easily reachable. However, education in this context could also be efficient for a number of reasons: students would have at least basic scientific knowledge and skills to appreciate the topics; they would be reached during their formative period, with consideration on security issues being embedded in their technical and personal formation; students, due to their age and context, may be more open to novel information than experienced, practicing scientists; embedding it in the higher education programmes (formally, but also informally) would help reaching large number of students at the same time as well as large numbers year after year and cohort after cohort.

nonetheless it still seems a prerequisite to construct a line of communication between scientists and security-concerned civil society and governmental organization.[266] It seems clear that a variety of options are available, and decisions on which to use should be done based on each national academic system after mapping them and evaluating their feasibility and expected effectiveness.

The final key question would be, assuming that the securitization move on establishing education as a deliberate disease risk mitigation measure has been accepted by its audiences, how can the efficacy of education be measured on competences, and, more importantly, on risks? Assessment on effectiveness are still to be completed (Rappert, 2007b), not only because of the recognition of the long-term (assumed) effects of education, as well as of the debates on establishing causative links between education and security, but also because indicators and metrics have not been directly addressed, drafted or systematically employed yet.

4.10 Conclusions

This Chapter discussed the securitization of education as a security tool to deal with deliberate disease risks, firstly explaining the role of education specifically and together with other measures of scientists engagement as described by security actors, and secondly presenting a number of attempted securitization moves. Calls for education have been analysed applying the historico-political securitization model. Securitizing actors, intended audiences, referent objects, and discursive devices have been analysed. Attempted securitization moves have been identified in discourses by international governmental organizations, national governments, scientific organizations, academia and civil society; and as mainly directed to two audiences, States and the scientific community. Six main securitization moves have been discussed addressed to States. I argue that the moves to recognize the value of education as a risk mitigation measure; on reporting to the BTWC on education efforts; and on funding initiatives and

[266] Another point of tension is the compromise between top-down approaches, which would assure an enforced and capillary implementation of education programs, but risk to not win the “hearts and minds” of the scientific community; or a bottom-up approach, on the initiative of civil society and engaged life sciences communities in a self-regulation mode, which could serve as a deeper engagement and mutual trust among communities but risks to result in scattered, low-funded and disorganized activities. The use of independent university coordination bodies, when present, may be an effective compromise between a small-scale initiative and a top-down approach (Mancini and Revill, 2009).

projects on education were largely successful, albeit to different extents. The moves to consider education as part of national implementation of the BTWC; and to involve national organizations competent on education had mixed success; and the move to develop national and international action plans on education was largely not implemented. Three main securitization moves have been discussed addressed to scientific communities. I argue that the urge on scientists to become aware and recognize the relevance of deliberate disease risks has gradually moved from being resisted to being accepted, though far from wide implementation. Some actions following up to the calls to develop and implement education, and to integrate education in higher education systems, however I suggest that implementation has not been widespread or necessarily sustainable. Some issues have been finally discussed regarding constructing and assessing education on deliberate disease risks, including the role of education as a security tool; contents of education; target students of education; and implementation strategies. I argued that these issues, coupled with limitations of some gap analyses so far, sustain the usefulness of design and evaluation tools for education as a potential tool to mitigate deliberate disease risks. The next Chapters will apply the educational science strand of the theoretical framework to propose some tools that may be useful in this sense.

5. Analysis

Chapters 3 and 4 presented the application of two strands of the theoretical framework for considering education as a tool to mitigate deliberate disease risks, discussing risk assessment and securitization moves. Chapters 5 to 9 look at the application of the third strand, methods of educational science, for designing and evaluating education as a measure of deliberate disease risks mitigation.[267] Chapters 5 to 9 address the various phases of the ADDIE cycle of instructional design (Analysis, Design, Development, Implementation, and Evaluation), both under the "education" and the "instruction design" plans. Chapter 5 starts with Analysis.[268]

Securitization moves and widespread recognition of education being a potential tool to mitigate deliberate disease risks, didn't necessarily include analysis of the learner populations or of the educational contexts on these subjects. Nonetheless, the need to gather information including on current levels of awareness was recognized as necessary to inform implementation initiatives (National Research Council, 2010). Indeed this would be part of Analysis, the first and data-gathering phase of the ADDIE model of ISD. Analysis is fundamental, as results will inform all subsequent aspects of instructional design, both for the Design and Development of education (the "education" plan) and for the success of initiatives aimed at supporting the adoption of such education (the "instruction design" plan). It's important that analysis is carried out thoroughly and at the beginning of the cycle, as well as integrated with additional information that may be gathered later. Analysis is "often labeled as unnecessary, too expensive, or too time-consuming" (Hodell, 2011 p. 24) but it is what contributes to an ISD approach in line with the learning-by-design pillar.

While all information, at all levels, may be useful during analysis, some is particularly important and should be considered first. Analysis should primarily determine where is education needed, on what, and who needs it (Goldstein,

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[267] As discussed in Chapter 2, three main areas from educational science are leveraged. The first one is Instructional Systems Design (ISD), in line with the learning-by-design pillar of educational science. Specifically, the ADDIE cycle model of instructional design is applied to education to mitigate the risks of deliberate disease. The second area is the evaluation of impacts of instruction, and specifically the model of four levels of impact. The third area is that of learner-centred teaching techniques, in line with the learner-centred pillar.

[268] The terms analysis, design, development, implementation and evaluation are used with the capital initial when referring to specific phases or corresponding activities within the ADDIE model of ISD.

1993). Hence early questions would be to define the problem and confirm it is instructional, i.e. a problem that can be fixed or ameliorated with education.[269] Answers to these questions have been proposed in previous Chapters.[270] I discussed there is a sort of consensus that education may be one mitigation measure within the web of prevention, one that may lower deliberate disease risks in the considered risk scenarios.

The second step is to check if and why we need new, more or different education than what we already have. In this Chapter, I present previous and original analyses on current educational opportunities as well as arguments on them being insufficient and in favour of improved education in terms of quantity and quality.

Analysis includes other information to gather before designing education, on both the population of learners and the context. Learners should be identified and demographic details[271] are useful to then tailor objectives and content during Design and Development. Task analysis of learners[272] can be particularly useful to understand their educational needs[273], and an area where our two education and instruction design plans would differ: students would be profiled based on the job tasks they may be responsible for in their future technical or managerial jobs; while educators would be profiled based on their responsibilities in their current jobs of academic decision makers and/or curriculum designers.[274] Another key area to analyse is the present level of content mastery by learners, or their current knowledge, attitudes and skills (Ree et al., 1995). For the education plan, this regards students' mastery of the subject matter deemed relevant for deliberate disease risks, such as laboratory

[269] Not all problems are instructional problems. Think for example to inadequate equipment, lack of communication, severe underfunding. Only instructional problems can be fixed with education or training.

[270] Where Chapter 3 defined the problem of deliberate disease risks and Chapter 4 presented attempts to securitize education on deliberate disease, presenting it as a (at least partly) instructional problem.

[271] Information as age or gender may be useful in some cases, but for our purposes specific details such as area of technical specialization and affiliation Faculty or department may be more relevant.

[272] This would involve description of the work functions to be performed, of their conditions or assumptions, to inform what would be needed to perform them (Salas and Cannon-Bowers, 2001).

[273] Some ISD case studies seem to suggest that Analysis should include definitions of the "topics" to be included in the course (Hodell, 2011 p. 27). Actually content should be determined by learning objectives (and not the other way around), which is done during the Design phase, and produced, based on learning objectives, during the Development phase.

[274] Such as Deans, Heads of Department, Course Coordinators, Professor, Lecturer, etc.

biorisk management and broader biosecurity, including dual-use; for the instruction design plan of work, this regards educators' mastery of the subject matter of instructional design. The relationship between learners and content could highlight critical points such as translation, meaning and preconceptions on terminology, placement of concepts in current educational opportunities, etc.

Knowing attitudes and opinions of the learner populations is fundamental to inform Design so that education can both be and be perceived as relevant. These include opinions of students and educators on deliberate disease risks and on education on deliberate disease risks.

Important information on the educational context to gather and analyse includes number of hours; balance between "theoretical" and "practical" work; academic credits; evaluation methods; teaching delivery techniques[275]; structure and processes of the higher education system, such as types of degrees, decision-making bodies, and the academic credit system; etc.

5.1 Analysis in education projects until 2011

In 2004, Dando and Rappert (Dando and Rappert, 2005; Rappert et al., 2006) carried out seminars[276] in HEIs to investigate the views of life scientists regarding the dual-use potential of experimental work. What started as an investigation on how to prevent misuse soon became an educational activity when it was apparent that participants had little knowledge and consideration of deliberate disease risks. The researchers encountered resistance to proposals on governing dual-use, as well as an "overwhelming sentiment" that life sciences and biotechnology do not contribute to the problem of potential misuse. Researchers found "little evidence that participants: regarded bioterrorism or bioweapons as a substantial threat; considered that developments in the life sciences research contributed to biothreats; were aware of the current debates and concerns about dual use research or; were familiar with the BTWC" (Dando and Rappert, 2005 p. 25). The format allowed introducing the seminars into the regular seminar series and an easier acceptance from HEIs, however they did

[275] For example, if learner-centred teaching techniques are known and applied in the context where the students learn; what innovative teaching implementation methods would be supported by educators; what teaching equipment is available; if distance or e-learning is a desirable and feasible option for designers.

[276] Involving twenty-four universities in the UK, one in another European country, and two pilots. Seminars included presentations showing information and questions to participants aimed to stimulate discussion.

not engage host universities in the Design or Development of the seminars and their contents.[277] Subsequent experience involving over a hundred seminars and thousands of practicing scientists in universities over the same model, suggested similar insights on the levels of awareness and knowledge (Rappert et al., 2006; Whitby and Dando, 2010b).

Other researchers used interviews or questionnaire surveys to identify the levels of awareness of life scientists; the existence and extent of considerations of deliberate disease risks (mostly including dual-use issues) in educational programs; or the opinions and attitudes of scientists. An investigation among European practitioners of synthetic biology (Kelle, 2007b) interviewed leading scientists[278] finding that awareness was particularly rare regarding information and proposals from security perspectives.

In the US, the American Association for the Advancement of Science (AAAS) identified fourteen universities that had educational programs that to some extent dealt with dual-use (National Research Council and American Association for the Advancement of Science, 2009). A survey among the Association's members on attitudes and actions on dual-use research received information from almost two thousands scientists, but with a low response rate making results not generalizable.[279] Among respondents, fifteen per cent indicated that they have taken actions based on concerns. On the other hand, two thirds of the respondents did not know if their scientific or professional societies had codes addressing dual-use issues. Respondents regarded more positively self-governance mechanisms, rather than mandatory regulation, and sixty-eight per cent of respondents agreed, "university and college students should receive educational lectures and materials on dual-use life science

[277] Furthermore, seminars targeted faculty members rather than students and did not involved HEIs because of a specific focus on (higher) education, but rather as a reachable segment of life scientists, rather than students.

[278] Specifically asking on on the "experiments of concern" described in the Fink Report; the recommendations of the Lemon-Relman Report; options of possible regulation of synthetic biology and the activities of the NSABB in the US.

[279] Nonetheless, it provided illustrative empirical data on awareness, risk perception, and opinions towards governance proposals for deliberate disease risks. A preliminary consideration is that while ignoring the reasons of non-response for about 80% of those surveyed, it is reasonable to think that at least a share of them did not have interest in, or awareness of, discussions on dual-use.

research" (National Research Council and American Association for the Advancement of Science, 2009 p. 119).

A 2007 survey focused on awareness and knowledge regarding bioterrorism among a sample of nurses and nursing students in Italy, on the basis that they would be the first responders in case of a security incident (De Felice et al., 2008). Results suggested "inadequate knowledge about the management of bioterrorism risks", with higher correct answers to questions related to biosafety and clinical practice than those related to deliberate disease risks. Undergraduate students had greater knowledge than both older students and practicing nurses, but the reason were not updated educational programs but rather that knowledge was "left too much to free initiatives (the press, Internet, etc.), whereas universities still only play a marginal role" (De Felice et al., 2008 p. 107). The study suggested that deficiencies in educational programs and teaching models should be corrected.

A year later, a survey on European universities reviewed 142 life sciences and biotechnology degree courses in 29 European countries, as well as attitudes of educators, regarding courses on biosecurity, bioethics and biosafety as well as references within courses to biosecurity, the BTWC, BW and/or arms control, dual-use and codes of conduct. Mancini and Revill identified only three courses that dealt specifically with biosecurity, which were optional. Only fifteen per cent of degree courses clearly included references to the studied items, although the lack of information prevented firmer data. Higher diffusion of bioethics (in 48 per cent of degree courses) and biosafety (in sixteen per cent of degree courses) suggested that these could be channels to introduce education on deliberate disease risks (Mancini and Revill, 2008; 2009). A similar process was used by researchers to survey degree courses in Japan, Israel, the UK, the Asia Pacific region and Ukraine. Researchers in Japan surveyed 197 degree courses (Minehata and Shinomiya, 2009; 2010), identifying a high presence of bioethics course but only three courses specifically dealing with biosecurity.[280] The survey on 35 academic degree courses in Israel found a wide presence of bioethics courses, but none on biosecurity (Minehata and Friedman, 2009). Revill surveyed the higher education offerings in the life sciences in the UK and

[280] The Japan survey was also able to identify that potential misuse was discussed more widely than in European universities, even if the specific name of "dual-use" was widely unknown.

A-level modules in high schools and textbooks. He found that six courses included some references to BW and one to other biosecurity-related issues (but none mentioned the BTWC), and that mentions on potential misuse were not included in A-level secondary education courses, even if broader ethical and social considerations of science were (Revill, 2009). A survey on ten countries in the Asia-Pacific region (Minehata, 2010) used similar methods, finding biosecurity mentioned as a topic in five cases out of 197 degree courses, arms control in three cases, and dual-use in nineteen cases, while a majority of degrees clearly presented a bioethics component. A survey on a sample of universities in Ukraine by the National Academy of Science of Ukraine presented comparable results on levels of awareness and consideration of the topics in higher education (Kysil, 2012).

At the Seventh BTWC Review Conference, Kenya reported that the level of awareness of misuse risks was limited in HEIs and research facilities, and that meanings attributed to the term biosecurity were competing (Australia et al., 2011 p. 9). Switzerland reported results from surveys on awareness of security risks among life scientists, revealing a "well-developed sense for aspects related to biosafety, but a considerably limited knowledge of aspects related to biosecurity", and that most scientists seemed to be unaware of the BTWC and/or of national legislation relevant for biological research (Australia et al., 2011 p. 12).

5.2 Demographics of students learners populations

One of the first aspects for Analysis is characterization of the learner population. Characterization of students is important primarily for the education plan of analysis, and indirectly for the instruction design plan. Pre-service students may have some characteristics of adult learners ("twenty-two or older who participate to purposeful education after being out of education for at least two years", according to Bonner (1982)) but be more apt than older learners to taking new knowledge in a structured educational environment. On the other hand, they will lack inputs of older learners: expertise, examples, practical skills, and prerequisites.[281]

[281] It should also be considered, as Koo and Miner (2010 p. 255) summarize, that "adults are active and reflective learners. They learn best when they are fully engaged in the learning process, and they bring their learning and experience into their workplace, professional practice, and community. Adults need to

Characterizing the student audience includes understanding the context and perspectives of their education. Simple information to gather on the former is what degree are they pursuing: are they at undergraduate, graduate, or postgraduate level? Or are they in a non-degree curriculum, such as a certificate or diploma? At what point of the degree are they? [282] Other information is the area of specialization: is the student completing, for example, a Medicine, Biology, Microbiology, Pharmacy, Public Health, Veterinary, or Biotechnology degree?

A useful way to characterize learners is task analysis, which has been applied to laboratory biorisk management in-service training student characterization (Delarosa et al., 2011; Grainger and Turegeldiyeva, 2015). Task analysis may be adapted to characterization of learners in higher education by asking: what tasks will this graduate have in their *future* job? Describing job perspectives and opportunities is common in higher education programs, as it is useful to explain to prospective students what they may do after graduating. For some degrees, job perspectives may be very specific, while for others (and in general for lower levels) there is a range of job opportunities.

An overview of information on population of potential learners from projects (see Table 6) suggests that often the more easily reachable group in the education plan may be undergraduate students. Indeed engaged faculty members in different occasions argued that undergraduate students should be targeted with some basic, foundational education.[283]

Analysis of learner populations within HEIs can provide indications on who should be prioritized among them, and if other cohorts should be added that are particularly in need of education. Anyway, prioritized groups may vary as it depends on the specific higher education context, job market, role tasks as well

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know why they are learning, what the goal is, and whether they can achieve the goal. Also, they expect immediate relevance to what they learn".

[282] Obviously, a student in the first year of a Bachelor will most likely have no previous technical knowledge or expertise; while a student who is completing a Master degree will recognize the scientific research process, how a laboratory is organized, and/or perform some techniques.

[283] It's also interesting to note that professors in different countries have independently suggested that education would be more appropriately introduced in the second year of a Bachelor degree: after the very basic science courses have been completed, but before specific techniques are learned and students start getting into the laboratory.

as perceptions of the engaged community. In the considered projects, for example, Country B and Country A University 2 participants, independently suggested students of Medical Laboratory Sciences as a priority with the argument that they would have direct responsibilities on laboratory biosafety and biosecurity. Some participants from Country D universities, as well as several European professors in EUBARNet, on the other hand, argued that postgraduate students in degrees such as biotechnology or virology would be a priority, because in their research environments they are more likely to deal with dual-use issues.[284]

[284] Different prioritizations within the learner population of students may also suggest different evaluations by respondents on the relative urgency of deliberate disease risks. Within the disease risk scenarios that I identified in Chapter 3, for example, the focus on Medical Laboratory Sciences students would suggest an intervention on the second risk scenario, with an external non-state threat seeking access to material or information assets. The focus on students in higher and/or more research-focused degrees suggests an intervention on the first and the third risk scenarios, in which broader biorisk management, security awareness, and dual-use ethics capacities would be more relevant as mitigation measures.

Table 6 - Overview of information on potential student populations

	Surveys on Professors						Surveys on Students	
Country	Country D	Country A University 2	Project 18	Country B	EUBARNet	Morocco[285]	Project 18[286]	Pakistan
Data/Tool	Email Questionnaire, 9 respondents	Email Questionnaire, 27 participants	Email Questionnaire, 376 respondents	Email Questionnaire, 17 participants	Web-based Questionnaire, 20 respondents	Questionnaire, 227 respondents	Pre-seminar Questionnaire, 453 respondents	Questionnaire , 448 respondents
Question	Which students do you teach to (degree specialization and level)?	What students do you teach to (degree, year)?	Faculty of affiliation and level of teaching	What types of students do you teach?[287]	What level do you teach in?	What is your level and discipline of intervention?	Degree and Discipline/Subject currently studying	Degree and Discipline/Subject currently studying
Degree Level								
Undergraduate	69%	99%	59%	69%	36%	64%	11%	24%
Master	23%	1%	29%	22%	31%	32%	65%	62%
PhD/PostDoc	8%		9%		31%	-	23%	9%
Course/Field of teaching or studying								
Medicine and Medical Specializations and Degrees[288]	33%	47%	18%	38%	-	20%	29%	25%
Medical Laboratory Sciences		30%		21%	-	-	-	-
Biotechnology and Biomedical Engineering	-	-	19%	3%	-	-	20%	45%
Biology, Biology-related degrees and Biochemistry	50%	16%	28%	21%	-	39%	45%	
Pharmacy	8%	29%	4%	11%	-	-	-	-
Food Science and Technology, Nutrition, Agriculture, Environment	-	-	3%	21%	-	7%	-	15%
Animal Health, Veterinary	8%	-	-	-	-	-	-	8%

285 Questions and categories translated from the original French questionnaire.

286 Eight seminars with students in seven Project 18 countries: Georgia, Jordan, Lebanon, Pakistan, Moldova, Ukraine, Morocco.

287 Discipline and degree program for each type of student.

288 Including Microbiology.

5.3 Education situational analysis

The next aspect to analyse pertains to the current status of education relevant for deliberate disease risks. This is key to identify gaps and needs, once it will be related to the learning objectives identified in Design.[289] Such analysis may focus on two dimensions: existing knowledge and skills in the targeted learners population, and existing educational opportunities. Both dimensions are useful to draw a baseline of the status of education relevant for deliberate disease risks, and inform subsequent decisions on Design.

5.3.1 Content mastery by student populations

Baseline content mastery by learners can be evaluated with different methods, according to the cognitive domain and level of learning needed. These concepts and the discussion on how to measure learning will be developed under the Design and the Evaluation Chapters, however we can present here examples and results for Analysis. Methods can include pre- and post-intervention tests; questionnaire surveys; and observation by instructors. Also defining exactly what should be the content to master depends on the specific learning objectives; however examples may include awareness on concepts and terms relevant for deliberate disease risks; ability to distinguish between safety and security concepts; or knowledge of the dual-use issues.

The survey on Pakistani students assessed their awareness of key terms, and asked to provide short definitions in their own words (Shinwari et al., 2011). A majority of surveyed students had at least heard of biosafety and bioterrorism; while only 38,6% had heard of biosecurity, 21,4% of dual-use research, and 12,3% of the BTWC. Awareness of the “biosecurity” and “dual-use research” terms increased with degree levels, being lowest among undergraduate and highest among doctoral students, and was higher among those students already involved in research.

[289] For this reason I prefer using “situational analysis” rather then “gap/needs analysis”. What are the actual education needs could be defined only with the definition of learning objectives, and the distance between the situation and such objectives.

Table 7 - Pakistan students questionnaire survey

		%yes							
Have you ever heard of…	%yes total	Degree level[290]			Researcher ?		Course/Field of Study		
		B	M	D	Yes	No	Biology/Life sciences	Medicine	Animal sciences
Biosafety?	54,5	55,6	55,4	65,8	83,9	44,2	61,1	37,7	70,3
Biosecurity?	38,6	25,9	42	63,2	62,7	29,7	40,7	22,1	54,1
Dual-use research?	21,4	18,5	23,6	26,3	33,1	17,1	25,7	6,5	24,3
Bioweapons?	58,3								
BTWC	12,3								
									%yes total
Do you know any local, national, or international organization working on regulating dual-use research and biosecurity?									4

Regarding students' understanding of terms, the majority did not answer the questions "what do you understand from the following terms" – even many of those who claimed to have heard of the terms before.[291] Only 7,3% of students provided a definition of biosecurity in line with the benchmark, and 13,2% of dual-use research. Clearly the difference between biosafety and biosecurity was a source of confusion, as many students attempted a definition for biosafety but left a blank for biosecurity.[292] For biosecurity, one example of definitions judged in line with its benchmark is:

> *"Awareness of the importance of material, culture you are dealing with. It can be moved, snatched, theft* [sic] *by someone who is not loyal to you, your lab, or your institution" [P8.02]*[293]

Among the few students who provided their own definition of dual-use research, while answers along the line of "research that can be applied both for good and bad purposes", such as

> *"Using both positive and negative aspects of scientific knowledge" [P1.01]*

> *"Scientific knowledge, ideas, techniques and materials are not only used for science of mankind but also for harmful aspects for human society" [P1.71]*

[290] Where B = Bachelor; M = Master; and D = Doctorate

[291] The term that received most definitions was "biosafety", but of those only about a quarter provided a definition judged in line with the benchmark definition from the WHO and the CEN.

[292] Or wrote "same as biosafety".

[293] As a reminder, quotes from questionnaires and other documents (such as design documents) are categorized following a coding scheme used throughout the thesis, in which the first letter and number identify the project and HEIs, respectively; and the second number the respondent. Thus in this case, for example, the quote is from participant 2 from HEI 8 in the Pakistan project's survey on students.

are considered in line with the benchmark definition, several students had a preconception of the concept that was distant from our benchmark and denoted various attempts to interpret the “dual” nature in the “dual-use” phrase, such as

> *“Getting double benefits from one use with little costs” [P1.20]*
>
> *“Use of knowledge and ideas regarding science in personal as well as community benefits” [P2.14]*

Understanding by students was often closer to benchmarks for the “bioweapons” and “bioterrorism” terms.[294]

Seminars within the EUBARNet series asked participating students, during pre-seminar tests, if they had “any prior knowledge about the potential “hostile use” of life sciences”, to which 70% of participants answered affirmatively.[295] The pre-intervention section of Project 18 questionnaires for students in conjunction with educational interventions included questions on students’ understanding of dual-use, safety and security, and the history of deliberate disease, in the form of multiple-choice questions. Results are reported in Table 8; “correct” options are highlighted.[296] The majority of students had an understanding of the “dual-use” term in line with deliberate disease risks literature, and a smaller majority grasped the concept of biosafety. However, the majority of students seemed not to have a “correct” understanding of biosecurity, laboratory versus broader risk mitigation, or international legal mitigation measures of deliberate disease risks.

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[294] One reason for this may be that terms have received media coverage, given that “newspapers” and “the Internet” were frequent answers to the question “from which source you mostly get your educational material”.

[295] Students learners participating to the seminars in Milan (2), Turin, Coimbra, Delft and Granada. Total 181 students. Local partners in the Bradford seminar did not include the question in the questionnaire for students. Answers “not much” from Turin questionnaires were coded as “no” (5 occurrences).

[296] “Wrong” options were taken from past surveys with students in previous projects by the author, such as previous research described in 5.1 and the Pakistan survey.

Table 8 - Content mastery assessment, students, Project 18[297]

What do you understand by the term "dual use" in the life sciences?	
The uncertainty on results characterizing new technologies	13%
The potential of obtaining positive results beyond expectations	7%
The possibility that they are applied both for peaceful and hostile purposes	76%
The ambiguity of life science and technology	12%
Laboratory biosafety refers to:	
Measures and policies for preventing the deliberate misuse of pathogens	25%
Measures for preventing theft and loss of pathogens	10%
Measures for preventing the unauthorized access to pathogens and toxins	30%
Measures for preventing the unintentional exposure to biological agents and toxins, or their accidental release	63%
Which statement about laboratory biosecurity is NOT true?	
It comprises policies and practices that require life scientists to consider the ethical, social and legal implications of their work	47%
It comprises measures and policies against the theft and loss of pathogens	21%
It comprises measures and policies against the unauthorized access to pathogens and toxins	12%
It comprises measures and policies that seek to prevent the intentional release of pathogens and toxins	20%
Which was the first International treaty to prohibit the use of toxic and biological weapons?	
The Hague Declaration, 1907	5%
Geneva Protocol, 1925	18%
Biological and Toxin Weapons Convention, 1972	54%
Chemical Weapons Convention, 1993	5%

5.3.2 Existing educational opportunities

Analysing existing educational opportunities is useful to understand if and how relevant topics are currently considered in HEIs. In the situational analyses results summarized in Table 12, it can be noted that some investigations asked about biorisk management, as well as separately about biosafety and biosecurity; others only asked of biosafety and biosecurity; or merged all in the same question; and several also looked at bioethics. Contents relevant for deliberate disease risks could be addressed in different existing courses and not only in those devoted to biosecurity *or* biosafety. When using questionnaires however, it seems advisable not to ask respondents about "biorisk management education content" if they have not yet been introduced to biorisk management. Asking about biosafety and biosecurity separately would already provide sufficient information as well as allow understanding on how the two dimensions are covered differently.[298]

5.3.2.1 Online investigations

The EUBARNet online investigation on universities suggested that 7,1% of analysed courses clearly included some possibly relevant reference to "security",

[297] "Right" benchmark answers highlighted.

[298] Also, this further supports why referenced definitions of terms were provided in surveys: a professor could easily check "yes we teach biosecurity", actually thinking to different meanings of the term. This is the same reason why, in some surveys, we asked if "biosafety" or "biosecurity" were used in other meanings than protection related to pathogenic microorganisms.

the majority being in graduate degree courses; safety-related topics were clearly mentioned in 18,2% of the analysed courses. The investigation in Region A suggested that 31% of the surveyed courses clearly included some references to BRM, safety or security management within or beyond the laboratory,[299] while 30% clearly included references to ethics, bioethics or responsible conduct of research content. The investigation on Country C universities' degree courses suggested that 27% clearly included some references to biorisk management, safety or security management within or beyond the laboratory, and 38% to ethics, bioethics or responsible conduct of research.

5.3.2.2 Questionnaire surveys

The questionnaire survey on Moroccan faculty members suggested that about a fifth of respondents taught some biosafety while less than one out of ten taught something relevant for biosecurity. Contingency tables suggest a relatively higher awareness among genetics faculty members;[300] a larger consideration in graduate courses[301] (although still less than a quarter of respondents); and higher consideration in science and technology schools than in science ones.

[299] For 13% there was enough data to judge there was no relevant content included, while for 56% it was unclear.

[300] The majority of respondents from each specialization, however, do not claim any reference to biosecurity at all.

[301] Master and License, in the Moroccan higher education system, respectively.

Table 9 - Educational opportunities, Morocco survey

In the courses/modules taught in the institution, are there references to the following subjects?	% yes	Most quoted courses/modules
Biosafety?	18,5	Microbiology, physiology, food quality
Biosecurity?	7,92	Quality control, environmental studies
Dual-use	1,76	Biology, Chemistry
Bioweapons	5,72	Genetics, Microbiology
The BTWC	1,32	Quality control

Are these subjects addressed during teaching seminars ?	% yes
TOTAL	12,33
Institution	
Faculty of Science and Technology	34,0
Faculty of Science	5,3
Level[302]	
Master	23,1
Bachelor	11,8
Do you make any references to Biosecurity?	% yes
Discipline[303]	
Physiology	16,7
Genetics	31,3
Chemistry area	14,3
Other	11,1
Ecology area	13,3
Biology/Life sciences area	9,3

Responses suggest some confusion on the biosafety and biosecurity terms.[304] Indeed some references to biosafety are reported in the context of *"management of risks connected to GMOs", "the Cartagena Protocol" [MH.02],* and *"potential risks linked to the introduction of alien species and genetically modified organisms" [MN.19].*[305] However, many references to biosafety are reported in the context of laboratory biosafety such as *"protection to avoid microbial infections" [MN.08], "systematic application of decontamination systems" [M.10].*[306]

Few comments are reported on relevant references on BW and dual-use, such as "*dual-use and biological weapons are one of the themes for essays [by*

[302] Of the first indicated "filière d'intervention" with more than 5 occurrences. Categories translated from the original French questionnaire.

[303] Of the first indicated "filière d'intervention" with more than 5 occurrences. Categories translated from the original French questionnaire.

[304] This is not surprising even considering that definitions were included in the questionnaire, firstly because in French the term "biosecurité" is often used for the two meanings and secondly because the same is used not only as protection against pathogens but also regarding GMOs.

[305] Translated by the author from the original French: *"la gestion des risques liés aux OGMs", "le Protocol de Cartagena" [MH.02] and "risques potentiels liés à l'introduction d'espèces étrangères et d'organismes génétiquement modifiés" [MN.19]*

[306] Translated by the author from the original French: *"protection pour ne pas avoir des infections microbiennes" [MN.08], "application systématique de systèmes de decontamination"* [M.10]

students]" [ML.08].[307] These references are reported within ethics education[308] such as *"in the framework of diagnostic techniques and transgenesis methods" [MM.05]; "laws on animal experimentation"; "confidentiality questions" [MF.03].*[309]

The survey of Pakistani students asked if and how they were ever presented with information regarding biosecurity or potential misuse of life sciences. Slightly more than a third of respondents replied positively, increasing with degree levels, and among those who perform some research.[310]

Table 10 - Educational opportunities, Pakistan survey

	%yes	Degree level			Researcher ?		Course/Field of Study		
		B	M	D	Yes	No	Biology/LS	Medicine	Animal Sc.
Have you ever studied anything related to these issues in your educational carrier?	36,4	33,3	37,7	52,6	74,6	23,5	41,9	32,5	40,5
									%yes total
Have you ever attended any conference or seminar on these issues?									7,4

Twenty-five per cent of respondents to the EUBARNet survey on faculty members reported that their HEI included some training on biosafety. Among respondents to the Project 18 questionnaire survey, 63% replied "yes" to "do you or your institution teach any specific courses focused primarily on biosafety" and 51% regarding courses on biosecurity. However, for the most part teaching did not go beyond "some references during lectures". "Bioweapons", "bioterrorism", "dual-use/misuse", and "laws prohibiting Biological Weapons" were only reported as "ever mentioned" in modules taught at respondents' HEIs in 25%, 28%, 28% and 21% of cases, respectively.

[307] Translated by the author from the original French: "*double usage et armes biologiques sont un des thèmes pour les exposés [des étudiants]" [ML.08]*

[308] Mentions of other bibliographic references linked instead to biosafety or biosecurity include WHO biosafety guidelines; the ISO17025 and ISO22000 standards; and national occupational health and safety norms.

[309] Translated by the author from the original French: *"dans le cadre de techniques diagnostique et méthodes de transgénèse" [MM.05]; "le lois sur la expérimentation animale" ; "questions de confidentialité" [MF.03].*

[310] Furthermore, answers suggest that the topics were not present in the scientific and academic debate, and that very few students had ever attended a conference or seminar on these topics.

Table 11 - Educational opportunities, Project 18 survey

Do you or your institution teach any specific courses focused primarily on…	Project 18					
	Email Questionnaire, 376 respondents					
	Yes	If yes, to what extent?		No	If no, why not?	
Biosafety	63%	There are one or more specific courses in the syllabus	18%	36%	Because we don't think this topic is relevant to our syllabus	11%
		There are one or more specific sections in the courses	38%		Because of lack of teaching time in the curricula	22%
		There are some references during lectures	45%		Because of lack of expertise and resources	38%
		There are dedicated institutes organizing seminars or mentoring	7%		Other	3%
		There are mentions in the recommended readings and textbooks	17%			
		Other	4%			
Biosecurity	51%	There are one or more specific courses in the syllabus	12%	49%	Because we don't think this topic is relevant to our syllabus	19%
		There are one or more specific sections in the courses	23%		Because of lack of teaching time in the curricula	25%
		There are some references during lectures	40%		Because of lack of expertise and resources	49%
		There are dedicated institutes organizing seminars or mentoring	5%		Other	6%
		There are mentions in the recommended readings and textbooks	18%			
		Other	3%			

Common patterns from questionnaire surveys from Country D, Region A, Country A University 2, and Country B (summarized in Table 12) are that existing educational opportunities included some considerations relevant for BRM. These considerations, however, were for the most part devoted to biosafety, and reported consideration of biosecurity was consistently lower. Still, content descriptions of reported biosecurity considerations included relevant examples even if mostly limited to laboratory biosecurity, such as: *"Accountability of laboratory workers […] (equipment and specimens); security of laboratory premises […]" [RA.01]; "During Pre-PhD course in research methodology. One chapter of the syllabus is on biosecurity. There is one PPT lecture. One hour dedicated to Biosecurity" [C.02].*

Ethics education[311] is generally more widely present than biorisk management considerations, but still no sample reports more than 60% consideration. Even among those, only minorities report any ethical consideration connected to dual-use, potential misuse, bioterrorism threats or deliberate disease risks.

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[311] Including bioethics, medical ethics, research ethics, responsible conduct of research.

Table 12 - Educational opportunities, overview

Country	Country C	Country D	Country A University 2	Country B	Region A	EUBARNet
Data/Tool	Online investigation, 50 degrees in 16 universities	Email Questionnaire, 9 respondents	Email Questionnaire, 27 respondents	Email Questionnaire, 17 respondents	Online investigation, 138 degrees in 14 universities	Web-based Questionnaire, 20 respondents
Question	Presence in degree syllabi of relevant educational content	Do students currently receive education on…	Do your courses currently include considerations on…	Do undergraduate students currently receive instruction on…	Presence in degree syllabi of relevant educational content	Does the University include training on…
BRM	27%	-	59%	Limited, largely confined to safety. Security is not mentioned.	31%	-
Biosafety		11%	62%			25%
Biosecurity		0%	11%			20%
Bioethics, Medical Ethics or Research Ethics	38%	33%	59%	Both stand-alone courses and training within broader courses	30%	25%
If yes, do they include considerations on dual-use issues, potential misuse and/or bioterrorism threats, relevant for biosecurity?	Ethics courses in Biotechnology degrees include topics as “bioterrorism”	11%	-	No mention of ethical topics related to misuse, dual-use, or social responsibility.	Not clearly; some courses merge safety, ethical, legal and policy topics related to science.	-

5.3.2.2.1 Existing opportunities to leverage

Analysis should not only point out what is missing, but also identify and credit what could be leveraged. The absence of education on deliberate disease risks does not mean that the presence of laboratory biosafety education should be belittled, as it signals a curriculum that could be improved as well as faculty who perceive the importance of biorisks. For example, the projects identified relevant modules and courses reported in Table 13. Professors from Country B reported examples of existing educational opportunities, such as:

> *"An Introduction on biosafety, biosecurity and biorisk principles is started to be given this year to fourth year students as a part of the Clinical Chemistry course." [B.02]*

> *"Use of PPE. Safe disposal of infective material. Topics included in the lab courses under universal precautions and safe disposal of infective materials. No Biosecurity." [B.03]*

In Country C, the syllabus of Biotechnology degrees include safety and ethics; some versions include safety and risk management as well as weapons ethics, but not laboratory biosecurity; others biosafety and bioterrorism, but not laboratory biosecurity.

Table 13 - Examples of existing educational opportunities

Project	Year	Language	Where
EUBARNet	2012	Main course reading is Casarett and Doull's toxicology: "*The new seventh edition features is updated throughout and includes many new contributors and new content on chemical terrorism*" (Klaassen et al., 2013)	Toxicology Master, Karolinska Institute
Region A	2013	Course of 3 hours weekly and 14 weeks, includes "Biosafety regulatory frameworks. Types of regulatory instruments […] Good Laboratory Practices. […] Risk analysis: risk assessment, risk management and risk communication. […] Fundamental ethical concerns of biotechnology"	Biotechnology Master
Country A University 2	2014	Course: Laboratory ethics and safety. Learning objectives include to describe principles and applications of ethics in medical laboratory research; […] to apply ethical code of conduct; general safety practices to laboratory work. […] to know employer and employee responsibilities for safety; […] to properly dispose laboratory waste.	BSc Medical Laboratory Sciences
Country B	2014	Course on laboratory management includes laboratory biosafety and bioethics content.	BSc Medical Laboratory Sciences
Country C	2014	Learning objectives include the use of standard safety measures while handling highly infectious material […] and ethics, responsibility, and first aid	BSc in Medical Laboratory Technology
Country C	2014	Course on bioethics and biosafety includes in learning objectives to be aware of the ethical issues concerned with the field; bioterrorism; ethical implications of biotechnology; social and ethical implication of BW; dispose of biohazards, the Cartagena Protocol.	MSc Biotechnology

5.3.3 Educators' experience and content mastery

Another useful aspect to analyse is the baseline experience and knowledge by educators, including the engaged faculty members of a project.[312] The Project 18 survey asked if participants had ever dealt in their courses with selected relevant topics. Reported experience was consistently lower for issues directly relevant for deliberate disease risks, such as dual-use/misuse, than for laboratory biosafety. Yet, positive replies are still higher than reported existing educational opportunities; a reason for this may be that survey respondents are a sub-group of faculty already more engaged than average on these topics, likely because of previous participation to awareness-raising initiatives.[313] Responses from Moroccan faculty members suggested that only 11,5% of respondents were informed of laws and regulations on life sciences research. Results are similar across the sample: educators coming from different Faculties, teaching in undergraduate or graduate courses, or in different subject areas (see Table 14).

Table 14 - Educators' experience, Morocco survey

Are you aware of any new laws, regulations or oversight bodies governing life science research and/or the publication of research?[314]	% yes
TOTAL	11,5
Institution	
Faculty of Science and Technology	12,0
Faculty of Sciences	10,5
Level[315]	
Master	7,7
Bachelor	12,3
Discipline[316]	
Biology/Life sciences area	11,6
Ecology area	0,0
Chemistry area	14,3
Genetics	6,3
Physiology	8,3
Other	0,0

Among respondents to the Project 18 survey, only about a third reported to know any regulations or local or international organization working on regulating dual-use research or biosecurity, prohibiting non-peaceful use of life science

[312] Yet not necessarily representative of the whole population of educators (in that country, in that sector) because of the lack of sample randomization and/or of statistical significance analysis, they would still provide an illustrative picture of educators' experience based on sets of quantitative and qualitative data.

[313] Further supporting this, positive answers to "have you ever dealt in your courses with…" are higher than those to "do you or your institution teach specific courses on…".

[314] Questions, items and categories are translated from the original French questionnaire (original question: "Etes-vous informé des lois, règlements ou des organes de contrôle régissant la recherche en sciences de la vie et/ou la publication des travaux de recherche?")

[315] Of the first indicated "filière d'intervention" with more than 5 occurrences

[316] Of the first indicated "filière d'intervention" with more than 5 occurrences

research or mitigation measures for deliberate disease risks from state threats as the BTWC. A third of professors participating from Country D mentioned they had previous training on biorisk management.[317]

5.3.4 Motivations, attitudes, opinions

Analysis is a good occasion to gain opinions from inside higher education systems on introducing or improving education relevant for deliberate disease risks. We can get a perspective on risk assessments from the higher education sector; opinions on current capacity and adequacy; the perceived urgency of education; suggestions on priority contents; existing teaching methods and resources; and information on accreditation contexts and processes.

5.3.4.1 Risk assessment

Surveyed Pakistani students were almost evenly divided on the question “do you think that your field of study involves such techniques that have the potential to be misused?”. However, a relative majority of students agreed that “undesired elements can gain access to scientific techniques for hostile activities”, suggesting a high assessment of laboratory biosecurity risks. However, students largely disagreed with a high dual-use risk assessment: the majority of students disagree with “laboratory setups at educational and research institutes can be used for preparation of materials for non-peaceful purposes”, a disagreement that grows with degree level and research experience.[318]

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[317] For those who added details, this training was mainly identified as based on Sandia’s GBRMC or from the WHO.

[318] We could infer that respondents would assess our third deliberate disease risk scenario (insider threat risk) higher than our second deliberate disease risk scenario (outsider threat risk). There is a higher risk assessment for dual-use risks only among medicine and microbiology students. Deliberate disease risk assessment was different for example on the side of Project 18 survey responding professors as 67% agreed to that their “field of study involves techniques that have the potential to be misused”.

Table 15 - Risk assessment, Pakistan survey

		%					
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	N/A
Undesired elements can gain access to scientific techniques for hostile activities	All	4,9	37,5	24,1	18,1	6,0	9,4
Laboratory setups at educational and research institutes can be used for preparation of materials for non-peaceful purposes	All	6,3	27,9	6,7	34,6	18,8	5,8
Degree level	Bachelor	5,6	26,9	7,4	26,9	28,7	4,6
	Master	6,9	27,9	6,5	37,0	15,2	6,5
	Doctorate	5,3	23,7	2,6	42,1	26,3	0,0
Researcher?	Yes	3,4	22,0	0,8	55,1	17,8	0,8
	No	7,4	31,3	8,7	28,4	20,0	4,2
Discipline	Life Sci.	4,2	25,7	7,2	35,9	21,6	5,4
	Medicine	19,5	22,1	7,8	18,2	26,0	6,5
	Microbiology	0,0	41,7	8,3	38,9	11,1	0,0
	Animal Sci.	2,7	29,7	2,7	54,1	8,1	2,7
	Environ. Sci.	1,5	30,3	6,1	43,9	18,2	0,0

5.3.4.2 Opinions on current capacities

The majority (55,6%) of surveyed Pakistani students agreed or strongly agreed that “national policy related to dual-use research and biosecurity should be developed”. Slightly over half of respondents agreed or strongly agreed that “scientific journals should have policies regulating the publication of dual-use research”, something particularly interesting as publication oversight may impact the scientific career of especially young researchers who may be expected to see it as a potential limitation.

Opinions and assessments from surveys on professors also suggest a perceived lack or inadequacy of capacities to deal with biorisks, including deliberate disease risks. Relative majorities of respondents to the Project 18 survey consistently judged “poor” availability of skilled staff and biosafety training. Available training was judged insufficient especially regarding higher education learners and teaching resources (see Table 16).

Similar assessments on inadequacy of capacity to teach in higher education were reflected in the answers to pre-workshop questionnaires by professors from Country C, Country D and Region A.[319]

[319] When only 37%, 22% and 20% of respondents from Country C, Country D and Region A surveys, respectively, agreed that “current trainers at the university have the necessary background and training skills to deliver BRM content”. The most mentioned need by Country B professors to the question “what do you believe are the five most important needs related to biosafety, biosecurity and bioethics in your country?” was “train-the-trainer”. Such a need to develop instructional capacity was followed by other categories also relevant for educational capacities on biorisk management, such as “development/strenghtening of national guidelines and standards”; “develop coursework for undergraduate

Table 16 - Current capacities, Project 18 survey

	%				
Please give your professional opinion on the following issues…	Excell.	Good	Avg.	Poor	N/A
Availability of skilled biosafety professionals	2	12	29	29	23
Availability of technically skilled workers for handling/transfer of potentially infectious material	1	13	24	29	28
Availability of infrastructure and professional staff to implement biosafety programs, including SOP's (Standard Operating Procedures)	1	12	20	38	25
Availability of accredited biosafety training for senior scientists	1	7	15	41	30
Availability of accredited biosafety training for university and graduate students	0	6	19	40	30
Availability of accredited biosafety training/teaching resources and materials	0	5	23	38	29
Availability of institutional biosafety oversight, such as laboratory (teaching & research) audits or regulatory compliance assistance, or institutional biosafety management committees	1	10	17	36	31

5.3.4.3 Importance of education

One of the reasons advanced by other experiences (Mancini and Revill, 2009; B Rappert et al., 2006) to explain difficulties in promoting education is the low perceived importance of biosafety and biosecurity in higher education. Analysing how educators perceive the priority of education is useful to know what to expect for engaging them in instructional design. It may however be of little value to ask, "Do you think knowledge on deliberate disease risks is important?" It may be more meaningful to put it in perspective asking to rank education with respect to other topics. If, for example, a course director would have to choose to make space between biorisk management education and another new subject area that the course is missing but is now regarded as necessary for technical training, what would be the choice? Safety and security should be integrated with the technical content, but this approach may force respondents to a more thoughtful assessment rather than just pick the "simple" answer. In this sense, in the more recent projects the question has been asked "how would you define the priority of incorporating new education on biosafety and biosecurity in educational programs?" (with respect to other subject areas you may have the opportunity to incorporate). The majorities of Country D, Region A, and Country A University 2 participants replied "high priority", or that they should be prioritized before other topics. A large part of the rest chose "average", or that they would have the same priority of other new topics, while virtually none indicated that there are other topics more urgent to incorporate. This certainly suggests that the surveyed professors believe education on

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students"; "Technical or laboratory equipment, infrastructure (and relative funding)"; "more practice training, workshops, visits, special initiatives"; "education for university students (in general: graduate or undergrad, educational kits, etc.)"; "formal curriculum development"; and "broader awareness raising, including "relevant people" as well as the public".

aspects of (bio)risk management is important, and at the same time provides a sort of "commitment" statement: as they supported it so much, they will be expected to work for advancing it.[320]

Particularly interesting from the Moroccan survey is the relationship between support to education and engagement of respondents. Those educators already mentioning biosecurity issues in their teaching have larger shares of "very important" and "important" on the need for awareness-raising for students, with respect to those not mentioning biosecurity or not answering that question at all. Professors aware of regulations on research give a similar support to education than those who are more ignorant of measures.

Table 17 - Educators' experience and support to education, Morocco survey

	How would you qualify the awareness raising of life sciences students on these issues?[321]						
	Very important	Important	Somewhat important	Less important	Not important at all	Do not know	No answer
Do you make any reference to the following topics [biosecurity, biosafety, bioethics, biological weapons, the BTWC, "dual-use"/misuse, codes of conduct, laws prohibiting biological weapons] ?							
Yes	88,9%	5,6%	5,6%	0,0%	0,0%	0,0%	0,0%
No	35,8%	47,3%	6,1%	0,6%	1,2%	5,5%	3,6%
No answer	54,5%	18,2%	4,5%	0,0%	0,0%	4,5%	18,2%
Are you aware of any new laws, regulations or oversight bodies governing life science research and/or the publication of research?							
Yes	69,2%	11,5%	11,5%	3,8%	0,0%	0,0%	3,8%
No	40,5%	43,2%	5,4%	0,0%	1,1%	5,9%	3,8%
No answer	37,5%	25,0%	0,0%	0,0%	0,0%	0,0%	37,5%

Comments from professors who qualified education on these topics as "very important" or "important" included for example:

> *"Contemporary issues of bioethics, such as the use of human embryos, organ donation, chemical products in agriculture, biological weapons and bioterrorism… the student needs to be sensitized so to at least participate to the debate as youth today and decision-maker tomorrow" [MD.15]*

[320] Interviewees in other projects expressed support, such as the Project 18 and Morocco surveys suggest; however high support could be explained by how the questions were posed. Ninety-seven per cent of Project 18 survey respondents replied "yes" to "do you think that awareness on biosafety, biosecurity and dual-use (misuse) should be raised among current and perspective life scientists in your country; while 81,9% of Moroccan professors qualified as "very important" or "important" "awareness-raising of students of life scientists on these subjects". Furthermore, this is regardless of the institution, the level of the degree level taught in, or the discipline of specialization, as in all subgroups there are majorities qualifying at least important the awareness of students.

[321] Questions, items and categories are translated from the original French questionnaire.

"[Regarding] biosafety, it's easier to make students interested because they feel personally concerned (their health) and in the daily practice. Biosecurity and bioethics do not regard the daily work but will be important depending on the professional domain they will work on and the responsibilities of their future jobs" [MF.01]

"Today's students are tomorrow's researchers, scientists and decision-makers, so their awareness-raising will allow introducing them now to this problem, whose dimensions increase with technological development" [MI.13]

"It became necessary to introduce teaching biosafety, bioethics, dual-use in the university programme because the life sciences have witnessed a rapid evolution in the last years and it is indeed normal to follow this evolution updating the modules traditionally taught" [ML.08][322]

On the other hand, the minority who marked education as less important observed that it is key not to exaggerate and cause panic, that education is important but *"awareness must be balanced and do not lead to paranoia" [MM.08]*,[323] and the positive economic and social impacts of life sciences and technologies should be underlined.

Also the majority of students responding to the survey in Pakistan agreed or strongly agreed with "education and research institutions should include study

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[322] Translated by the author from the original French: "*Sujets d'actualité de bioéthique, comment l'utilisation des embryons humaines, le don d'organes, le produits chimiques dans l'agriculture, les armes biologiques et le terrorisme biologique… l'étudiant a besoin d'être sensibilisé pour au moins pouvoir participer au débat en tant que jeune d'aujourd'hui et décideur demain"* [MD.15]; *"[Sur la] biosécurité est plus facile de intéresser les étudiants pourquoi ils se sentent concernes personnellement (leur santé) et a l'immédiat. La biosûreté et la bioéthique ne l'interpellent pas a l'immédiat mais aura son importance selon le domaine professionnelle qu'ils vont intégrer par la suite, et les responsabilités afférentes au poste occupé " [MF.01]; "Les étudiants d'aujourd'hui sont les futurs chercheurs ; scientifiques et décideurs, donc leur sensibilisation va permettre de les initier dès maintenant sur ce problème dont l'ampleur augmente avec le développement technologique" [MI.13]; "il est devenu nécessaire d'introduire l'enseignement de la biosécurité, de la bioéthique, du double usage dans le cursus universitaire car les sciences de la vie ont connu une évolution rapide ces dernières années et il est tout a fait normale de suivre cette évolution en apportant des modifications dans les modules enseignés classiquement". [ML.08]*

[323] Translated from the original French: "*la prise de conscience doit restée mesurée et ne pas verser dans la paranoïa" [MM.08]*

materials on dual-use, biosafety, and biosecurity in your course work". Comments from students suggested educational initiatives such as

> *"Seminars and classes should [be] arranged about the awareness according to biotechnological and bioscientific processes, uses and its misuses, and about its laws and implementations" [P5.54]*

> *"Such courses should be introduced at college and university level to create awareness among students" [P6.24]*

5.3.4.4 Optimal strategies for education

Questions in the surveys asked for respondents' opinions on a series of statements to analyse options for education. Responses include that, for example, instructional design training is needed for lecturers to be able to deliver education on the subject. Other items related to the ideal contexts and formats, such as: should it be a dedicated course, or rather spread over other courses to embed it with technical education? Should it be taught in courses, or be part of extra-curricular activities? Should education be mandatory or optional?[324]

From the surveys on Country C, Country D and Region A participants, there is support for introducing education within formal credited courses, both newly developed and existing ones that could be reviewed or expanded. There is also support, yet smaller, on using more flexible extra-curricular activities for students. What receives less support is that education should be in elective activities of courses. Further discussion with Country C, Country D and Region A participants confirmed they supported education to be mandatory for students, not optional.

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[324] As introduced in the previous Chapter, each of these options has general advantages and disadvantages. Creating a dedicated course may be the best way to ensure biorisks have enough consideration in degrees, and do not depend from the initiative of an individual interested lecturer. On the other hand, it may be more effective in terms of integration with technical education if bits of it are taught within other discipline courses. Introducing education in formally structured courses, which generally have defined learning objectives and evaluation methods that assess if students actually achieve them, would raise chances that education is imparted, but on the other hand extra-curricular activities have more flexibility to introduce learner-centred techniques. Finally the risk of establishing a mandatory requirement is to have a "ticking the box" approach if students are not interested, while elective education would make sure only interested students take those modules, arguably with higher retention.

Regarding what existing educational avenues could be used, respondents from Region A suggested laboratory techniques and environmental health courses, while professors from Country B mentioned microbiology courses and first aid training, and European participants bioethics courses.

Surveys were also useful to analyse what is available and desirable in the instructional context. For example, it was consistently reported by professors that undergraduate students classes are considerably larger than graduate students ones, in the order of hundreds versus tens of students, something that has to be taken into account during instruction Design, Development and Implementation of education.

Interactions with Country B participants suggested that instruction modules should be set to two hours slots. Their proposals for modules included theoretical lectures, practical work in laboratories, visits, and activities such as case studies or fieldwork.[325] Suggesting a potential international alignment, the relative majority of professors from Region A countries also believed that education on biorisks could fill a semester course.[326]

5.3.4.5 Identified challenges

Particularly interesting is how potential challenges identified by faculty members on introduction of education on management of biorisks, particularly deliberate disease risks, are common across different regions and countries, while yet some challenges are bigger or more pressing in some contexts than others.

Reported challenges can be categorized in four main categories: lack of capacity in faculty members, on the subject matter, on teaching it or on both; lack of teaching time and space in curricula; bureaucracy for changing educational programmes and curricula; and lack of support from management and leadership.

[325] According to that discussion, modules could be organized in semester-long courses with one theoretical two-hours module and one non-theoretical two-hours module each week.

[326] Alternate options and possibly more feasible than establishing new courses were also suggested in conversations with Region A professors, such as a module of ten to fifteen hours to be inserted in existing courses, possibly to be expanded; or an intensive, dedicated course that becomes a prerequisite for students before they can start laboratory work, do research, or graduate.

Lack of "subject matter knowledge" or of "expertise" was the most quoted reason for non-inclusion of education by respondents to Country D and Project 18 surveys. Moroccan professors also addressed lack of capacity, for example:

> *"It is necessary to give more means to teachers who want to invest in the subject" [MG.06]*
>
> *"A national law on bioethics, a coordination among teachers of the subjects in universities, and finally an available bibliography are necessary" [MN.16]*[327]

Comments from Region A professors regarding challenges and barriers to the introduction into academic curricula included:

> *"Faculty capacity: the faculty should have thorough understanding on biorsik management in order to figure out ways to integrate BRM in to academic curricula." [RA.5]*
>
> *"Lack of qualified staff to handle and teach it." [RA.17]*

Besides subject matter and instructional capacities, however, the other mainly quoted challenge is the lack of teaching time and space in curricula. So this was quoted from Morocco, with the difficulty of creating new courses or expanding existing ones:

> *"[there is the] problem of hours workload, which is limited and does not allow having a longer course to introduce the issue of bioterrorism and laws regulating research" [MN.13]*[328]

While expansion of existing courses seemed feasible to some Region A respondents:

> *"Including a chapter within an existing course, namely 'Environmental Health' is possible. This course covers the topic of environmental risk*

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327 Translated from the original French: *"Il faut donner plus de moyens pour les enseignants qui veulent s'investir dans le matière" [MG.06]; "Il faut une loi nationale sur la bioéthique, une concertation entre enseignants de la matière dans les universités marocaines et enfin une bibliographie disponible" [MN.16]*

328 Translated from the original French: *"[Il y a le] problème de volume horaire qui est limité et ne permet pas d'avoir un cours plus long pour introduire la question du bioterrorisme et les lois régissant la recherche" [MN.13]*

assessment. This can be extended to Biorisk management then entitled Environmental and Biological Risk Management" [RA.12]

But still there are comments about the difficulty:

"Introduction of a new course in a program is always a challenge with regards to time allocation in a time table especially if it is already loaded" [RA.1]

"Hours or credits as it is are quite congested and adding new content may be challenging " [RA.8]

Another challenge is bureaucracy to change formal curricula to insert new, or change existing, courses. Certainly this is different from country to country (and is further discussed in the next paragraph), as it appears more pressing in some surveys than others. So participants from Region A commented:

"There is bureaucracy in curricula review that delays the process even when necessary." [RA.9]

"Institutional bureaucracy: curriculum approval takes too long." [RA.10]

Support from management and leadership in HEIs is hence fundamental to address and overcome other challenges. As professors from Region A put it, support is important:

"Not all is lost as the leadership of the faculty is keen on training in this area and some of the biosafety committee members have been trained" [RA.9]

"Interest from top leadership including faculty on need for BRM" [RA.15]

Something to also consider is the potential confusion on the key terms of biosafety and biosecurity. Especially in academia, there is the possibility that they are used in different ways; for this reason several surveys asked participants if HEIs also used the words in different ways. While results reported in Table 18 suggest that the majority of participants used biosafety and biosecurity in the same context of prevention of risks from pathogens and toxins, alternate meanings are also present and should be taken into account.

Table 18 - Meanings of biosafety and biosecurity

Country	Country C	Country D	Region A	Country B
Data/Tool	Email Questionnaire, 9 respondents	Email Questionnaire, 9 respondents	Email Questionnaire, 21 respondents[329]	Email Questionnaire, 17 respondents
Are alternative concepts of biosafety/biosecurity also used?	No, they are used in the same context: prevention of harm from pathogens and toxins (37%); Yes, the are used in the context of GMOs regulation (25%)	No, they are used in the same context: prevention of harm from pathogens and toxins (78%)	No, they are used in the same context: prevention of harm from pathogens and toxins (44%); Yes, the are used in the context of control of agricultural contamination (20%); Yes, the are used in the context of control of protection of biodiversity (20%)	No, they are used in the same context: prevention of harm from pathogens and toxins (55%); Yes, the are used in the context of GMOs regulation (22%)

5.3.4.6 Accreditation systems and processes

There is not an international model for how higher education contents are introduced in degrees. In some countries, HEIs are independent and can autonomously decide what to teach, and in some cases, individuals responsible for the single courses can make decisions. More commonly however, HEIs have to comply with guidelines on what to teach. The government may issue direct guidelines, through the Ministry competent for higher education, or by a subject matter Ministry (such as Ministry of Health for medicine degrees, Ministry of Agriculture for agrarian sciences degrees, etc.) In other cases influence on HEIs on what to teach may come from professional sectors, for example if a professional association issues minimal requirements for graduates, or if a certain set of skills are required to pass the national exam for becoming a practicing professional.

Table 19 - Accreditation processes

Country	Country C	Country D	Region A	Country B
Data/Tool	Email Questionnaire, 9 respondents	Email Questionnaire, 9 respondents	Email Questionnaire, 21 respondents[330]	Email Questionnaire, 17 respondents
What is the process of introducing new course(s) with dedicated credits into the academic program of your institution?	The process to approve new courses is internal to the institution and decisions on changing programs can be taken and implemented directly (62%)	The process to approve new courses is internal to the institution and decisions on changing programs can be taken and implemented directly (44%)	The process of approving new courses is internal to the institution, but it does require multiple formal review and approval by various management levels (41%)	The process of approving/accrediting programs requires approvals by Department, Faculty, University and finally by the Accreditation Council at the Ministry

Different processes will require different approvers and decision makers. In some contexts, for example, inserting a new course would require approval by

[329] Including 14 university professors

[330] Including 14 university professors.

various bodies.[331] Region A participants also noted that curriculum review is often planned for pre-determined time windows. Another example comes from Country B:

> *"[The] process [of approving a new curriculum] starts in the meeting of the Department staff and agree to design a new course curriculum, Heads of Departments, Faculty Dean, University Senate and finally it [is] approved by Ministry of Higher Education and Scientific Research"; [B.05]*

Table 19 reports results of a question where participants were asked which statement best described the process of introducing new courses, from one describing a very autonomous and flexible process, to another very formal and fixed.[332] It is also useful to investigate if there are systems to introduce new contents in universities top-down, complementing the bottom-up approach of universities reviewing their curricula. In some countries, governmental or non-governmental bodies issue guidelines to both assure minimal standards of quality of science education and to harmonize education on the same subjects across the country.[333] Such a coordinator may help in promoting education in two ways: firstly, it may directly be received by academic decision makers (such as deans) who would decide to revise their courses; secondly it may help those lower level educators who are interested in inserting new education and can use it to press on their superiors.

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[331] For example as one participant from Region A commented, *"Several steps and boards have to approve changes in curriculum before training can begin – the Department, the School, the Board, the College and the Senate" [RA.12]*

[332] A relative majority of Country D participants responded that universities could approve introduction, however clarifying discussions during the ISD workshop suggested that for most universities approvals at higher levels are indeed needed. At the same time, professors responsible for a course could independently change up to ten per cent of course contents without having to formally resubmit the entire course.

[333] One example is an accreditation council in Country B. This Council is composed of scholars on the various disciplines and is tasked with drafting minimal requirements for higher education and promotes harmonization of degrees. However as described by Council members, its influence is still low as HEIs have historically had large freedom on what and how they teach. Notwithstanding challenges, the Council was drafting designs for reviewing Country B's academic programs. As a result of our project's instructional design, Council members were inserting learning objectives on biosafety, biosecurity and bioethics in the relevant public health, biosciences and medicine degrees as they were going through their review. See Chapters 8 and 9 for further discussion.

A similar experience was with the ISIS Euro-European Master in Neuroscience and Biotechnology. In the early discussions about the design of the ISIS Master syllabus, pointing at how the Dublin Descriptors[334] required that the students gain the ability "to inform judgments that include reflection on relevant social, scientific or ethical issues" (Adelman, 2009 p. 28; Bologna Working Group, 2005 p. 68) was important to decide on the inclusion of a mandatory course on ethics of biotechnology and neurosciences.[335] Another aspect useful to analyse is the requirements on the formats and quantities for courses. Many HEIs use credits as metrics for educational and learning activities.[336]

[334] New degree courses designed in the EU have to comply with the generic Qualifications Framework of the European Higher Education Area (also refereed to as the Bologna Process), also known as the Dublin Descriptors.

[335] And that course included a module on dual-use and security issues in neurosciences.

[336] In the Country B's system, for example, one credit-hour equals fifteen contact hours of classroom lectures or activities or thirty contact hours of practical/lab activities or tutorials (hence a classroom contact hour equals two practical contact hours); however a course cannot be shorter than one credit-hour with at least one classroom or two practical contact hours a week for a fifteen-weeks semester. In both Country B and Region A, a one-semester course would total 45 contact hours corresponding to 30 credit hours. In Europe, the European Credit Transfer System suggests that one credit equals 25 hours of workload for the students, spread over classroom, group work, practical of self-study activities.

Table 20 - Motivations, attitudes, opinions: overview

Country	Country C	Country D	Region A	Country A University 2	Project 18	Morocco[337]
Data/Tool	Email Questionnaire, 9 respondents	Email Questionnaire, 9 respondents	Email Questionnaire, 21 respondents[338]	Email Questionnaire, 27 respondents	Email Questionnaire, 376 respondents	Questionnaire, 227 respondents
How would you define the priority of incorporating new education on biosafety and biosecurity in educational programs? (% of High priority: it is more urgent than other new topics that could be incorporated)	37%	77%	48%	70%	97%[339]	82%[340]
Current trainers at the university have the necessary background and training skills to deliver BRM content[341]	37%	22%	20%	-	6%[342]	-
BRM should be developed as a specific and new course with dedicated credits	87%	66%	80%	-	-	-
BRM should be the topic of elective activities or courses	50%	40%	31%	-	-	-
New content on BRM should be inserted in extra-curricular activities, as expanding credits for existing courses is very difficult	37%	44%	42%	-	-	-
New content on BRM should be integrated into existing courses, expanding their hours/credits	87%	66%	95%	-	-	-
How many hours do you believe should be devoted to BRM in the academic curricula (relative majority)	-	-	More than 20 hours (41%); between 5 and 10 hours (31%)	More than 20 hours (33%); Between 5 and 10 hours (30%)	-	-
Do you have any plans to change your course or module to accommodate such topics?	-	-	-	-	69%	46%
Do you think your field of study involves techniques that have the potential to be misused?	-	-	-	-	67%	-
If biosafety or biosecurity are not taught, what is the reason in your opinion?[343]	These subjects are currently not a high priority, compared to other subjects (50%)	Lack of subject matter knowledge, teaching capacity or expertise (33%)	-	-	Lack of expertise and resources	-

337 Questions and categories translated from the original French questionnaire.

338 Including 14 university professors.

339 "Do you think that awareness on biosafety, biosecurity and dual-use (misuse) should be raised among current and perspective life scientists in your country?"

340 "Comment qualifiez-vous la sensibilisation des étudiants des sciences de la vie à ces sujets?"

341 Yes or agree + strongly agree, or excellent + good.

342 Opinion on "availability of accredited biosafety training and teaching resources for university and graduate students"

343 Relative majority.

5.4 Conclusions

Information from investigations and surveys from several countries suggest results that have traits in common. Students' content mastery of topics relevant for deliberate disease risks is basic or non-existent; students generally even have a low awareness of important concepts for deliberate disease, and evidence suggests that many do not know that the BTWC exists. Within the biorisk management spectrum, knowledge is higher for biosafety than for biosecurity, but confusion between safety and security is common.

Existing educational opportunities are scarce and insufficient, especially for the deliberate disease side of biorisk management. However, existing opportunities were identified as useful to leverage during Design of education and for the instruction design plan of the research. In investigations that looked at safety and security together, current considerations stop at about a third of considered samples, but when viewed separately, references in education to deliberate disease risks (such as biosecurity, dual-use issues) are less common, ranging from less than a tenth to a quarter of occurrences. Possibly more importantly, existing references in education are generally qualified as not more than mere "mentions", and mostly focusing on *laboratory* biosecurity. Existing educational opportunities on biorisk management seem more common for higher degrees;[344] learners who already do research; and are higher in life sciences and biotechnology areas than in medicine and public health areas.

While we could map some educators' experience on laboratory biosafety, their knowledge of laws and regulations relevant for deliberate disease risks mitigation; prohibitions on deliberate disease; or organizations working on biorisk management, is scarce to non-existent. Developing capacities on biorisk management and teaching biorisk management is identified as one of the most pressing needs by participants and respondents in multiple countries.

Indeed many engaged faculty members from higher education believe that incorporating new education on biosafety and biosecurity is a high priority. Furthermore, awareness among faculty members is related to heightened interest and commitment to support education implementation, which speaks to the value of faculty engagement and instructional design activities.

[344] While suggestions from faculty members are that education should start earlier.

The support from educators is strong for the introduction of biorisk, including deliberate disease risks, management education in formal courses, either by designing new courses or reviewing existing ones. There is also support, yet smaller, for less formal extra-curricular educational formats; however education should be mandatory, not optional. Identified challenges, besides the primary one, and already mentioned, of lack of capacity, are time for education; bureaucracy for changes in higher education; and support from leadership. Challenges impact on accreditation for new or reviewed formal courses that should include education, that however have different processes in different countries and context, leaving more or less autonomy to HEIs. Considering these processes is useful for the instruction design plan of the research.

6. Design

Design is a key component in the ADDIE ISD cycle and is central to the instructional *design* process. In fact, the phases of the ADDIE cycle are sequential but in some way also overlap each other, and Design has a central role (Kirkpatrick and Kirkpatrick, 2007).[345] The Design phase "delegates" some tasks to the Analysis, Development, Implementation and Evaluation functions, while ultimately controlling the whole ISD process. Nonetheless, Design as Analysis is often overlooked by traditional instructional approaches to education, when lecturers may rush to the Development of instructional materials, leading to teaching "what the instructor wants" and not "what the student needs". On the instruction design plan of the research, stressing the importance of Design is almost more important for designing pre-service education than in-service training. For example, institutional staff designated to become internal resident trainers in an in-service context often do not have previous experience in training others. They hence need coaching and practice on the Implementation of training contents. Educators in universities, conversely, have more experience of delivering education.[346] They will need relatively more coaching on Design to address the specific educational context of HEIs, which is often more formalized than internal staff training in an organization.

6.1 Learning objectives

A key question to consider in Design is, based on the learner population(s) identified in Analysis, what do we want them to learn that will contribute to mitigating the risks of deliberate disease? That is, setting learning objectives.

6.1.1 Preliminary objectives identification

A preliminary overview towards learning objectives includes opinions of educators on the most needed competences for the students. Useful indications come from pre-ISD workshop surveys. Investigating educators' opinions over needed competences for students is strategic at this point for a number of reasons. Firstly, it provides to the instructional designer an idea of what educators see as priorities within education, bridging the Analysis and Design phases of ADDIE. Secondly, it impresses on participants the concept of

[345] As Hodell (2011 p. 55) describes it, "many of the separate components of the instructional design process occur in the other four elements and are simply managed by the design function".

[346] As most likely they are professors and lecturers who teach students on a regular basis.

learning-by-design while they provide Analysis information on learners and instructional context. Thirdly, it entertains features of learning objectives to participants, such as cognitive domains (“knowledge”; “attitude”; “skill”).

There are commonalities among competences for students on management of biorisk, including deliberate disease risks, most quoted by participants from different countries and projects. Table 21 reports categorized[347] answers and examples from Region A; Country B; Country C; Country D; and Project 18 educators. Competences that were quoted in all surveys include: knowledge of the basics of biosafety, biosecurity, biorisk management and biosecurity ethics; knowledge of risk assessment; knowledge on biological hazardous waste management. Competences among the most quoted ones in multiple surveys, but not all, include knowledge of ethics of dual-use and misuse; PPE use skills; handling, storing, transporting and shipping infectious substances; incident and emergencies management; assessing biorisk management performance; risk communication.

[347] Quoted competences were categorized and divided in the broad “know” and “skills” domains. See Chapter 1 for more information about methodology for analysis of qualitative data from questionnaire surveys.

Table 21 - Needed competences for students, opinions of educators

Categorized Competence[348]	Cognitive Domain	Region A	Project 18	Country B	Country C	Country D
		Email Questionnaire, 21 respondents[349]	Email Questionnaire, 376 respondents	Email Questionnaire, 17 respondents	Email Questionnaire, 9 respondents	Email Questionnaire, 9 respondents
		What do you think would be the most needed competencies for your staff/students related to biorisk management?	What would you like to see those "educated" doing as a result of the process of [biosecurity and dual-use] education?	Please Identify the three learning objectives that you believe are most important for your students related to biosecurity, bioethics and biosafety	Please identify the three learning objectives that you believe are most important for your students related to biosafety and biosecurity (biorisk management)	
Basics of biosafety, biosecurity, biorisk management and ethics relevant for biosecurity	Know	Understand biosafety and biosecurity (RA.03); principles of biosafety and biosecurity (biorisk management) (RA.02, RA.07; RA.12; RA.13; RA.16))	Be more vigilant (locking doors)	Principles of safety, security and ethics in the laboratory	Basics of biosafety and biosecurity (C.01)	Containment principles and how to prevent unintentional exposures (D.02); what is biosecurity (D.02)
Risk assessment (risk and hazard identification, risk characterization and evaluation)	Know	Risk assessment (identification, characterization) (RA.05; RA.06; RA.07; RA.08; RA.13; RA.16; RA.20); Evaluate biological hazards and determine risks (RA.12)		Recognize biorisks and other risks	Identify what they are handling; identify consequences of exposure or contamination (C.02)	The risks (D.05; D.06); How to identify the hazards and evaluate the risks (D.03); recognize hazards (D.09)
Biological hazardous waste management and disposal	Know	Management of laboratory waste (RA.07)		How to manage and dispose biological waste	Safe disposal of agents of biorisks (C.04)	How to get rid of these risky materials in a safe way (D.05)
Ethics related with dual-use and misuse	Know	Issues related with bioethics and dual-use (RA.07)	Refusing involvement in biological weapons-related activities; being more careful in their publications and research.	Research, clinical and experimental ethics		Ethical principles to ensure biotechnology is not abused (D.09)
PPE	Skill			Apply PPE		Use PPE (D.04; D.07)
Handling, storing, transporting and shipping infectious substances	Skill	Apply procedures for transporting and storing biological hazards (RA.07)		Apply material control & accountability, inventory, storage; transport and shipping procedures for infective material		How to transport dangerous pathogens (D.09)
Incident/emergencies management (preparedness and response)	Skill	Incident management and response (RA.07)	Reporting incidents that are suspicious		Handle emergencies while working (C.01)	Act and work in right way during biological and chemical accidents (D.02)

348 Quotes are categorized following a coding scheme used throughout the thesis for questionnaires and documents such as design documents, in which the first letter (and number, in case multiple HEIs are involved) identify the project (and HEIs); and the second number the individual respondent. So, for example, RA.07 identifies participant 07 in the Region A email questionnaire; D.04 participant 04 in Country D email questionnaire.

349 Including 14 university professors

Performance of biorisk management	Skill	Measure and monitor the performance of a BRM system (RA.12)				Do the continuous improvement of that system (D.03);
Risk communication	Skill	Communicate risk information to others (RA.12; RA.13; RA.16)			Communicate and explain risk	

6.1.2 ISD learning objectives definition

Notwithstanding useful indications from educators' opinions on needed competences, ISD provides detailed indications on defining effective learning objectives. ISD guides (Hodell, 2011) on elements that should be included in well-written learning objectives: Audience, Behaviour, Condition, and Degree. Firstly, the learning objective should give a clear definition of the student, indicating the specific program they are pursuing, at what level in the higher education *cursus* they are, and any other information that helps defining them. The Audience part of the learning objective should be written with an individual student in mind, rather than a class, to later make evaluation easier.[350]

Secondly, objectives should define the desired learning[351] from the student. This is where specific levels and domains of learning should be identified. The concept of levels of learning derives from the taxonomy first proposed by Bloom (1956). As explained in Chapter 2, learning may be different both in terms of complexity (some learning cannot be achieved if others are not completed before) and of cognitive domain. For example, assessing risks and benefits of a situation is a relatively advanced capacity that cannot be mastered if basic concepts are not known. Being able to practically perform a task is a different cognitive domain ("do", "skill") than considering something theoretically ("know", "knowledge").[352] The action verbs suggested by learning taxonomies (Krathwohl, 2002)[353] are of great help to design clear learning objectives. A theoretical, relatively low-level learning objective may be described as "list", "memorize", etc. A theoretical but higher-level learning objective could be described using "critically assess", "judge", or "forecast". Practical learning objectives could be associated with action verbs as "perform", "use", "complete", "build" etc. In any case, a specific verb is preferable than the generic "learn". The achievement (or lack) of the desired learning should be observable and measureable. The

[350] So for example rather than "students of biology", a designer should be precise with "the student of the course '201 Biosafety, Biosecurity and Bioethics', in the second year of the Bachelor of Science in Medical Laboratory Sciences".

[351] Hodell uses "behaviour" to indicate the learning (even at theoretical levels), and it is different to the "Behaviour" discussed as Level 3 impact of education under the Evaluation Chapters of the thesis.

[352] The two layers are connected but independent: a practical skill may be higher learning level than a theoretical one, but also the other way around.

[353] See also Adelman (2009 pp. 68–70) on the "centrality of the verb" to explain learning objectives in different cognitive domains and levels of a qualification framework.

learning objective should also state any condition that is needed for the objective to be met.[354] Finally, the learning objective should state the degree to which the behaviour has to be met, possibly mentioning indicators and acceptable thresholds.

The concept of learning objectives is already established in HEIs in most countries. Different higher education systems, and even different HEIs within the same system, may define and refer to learning objectives in different ways and using different categories. This is important to consider, to make sure learning objectives are designed in the easiest way for inclusion in the local higher education system. Useful information can be leveraged from Analysis: for example, Country B's academic context calls learning objectives Intended Learning Outcomes (ILOs)[355] categorized in four categories crossing levels of learning and cognitive domains. The syllabus of an existing "Bioethics & Biosafety" credited course at a HEI in Country C uses "Course Objectives" for what we call instructional objectives, and "Course Outcomes" for what we call learning objectives. The system at Country A University 1 distinguished between "learning objectives" (what I would define "know" cognitive domain competences acquired during the course) and "learning outcomes" (what I would define "skill" cognitive domain competences for application at the end of the course).

6.1.3 Learning objectives for the instruction design plan

What could be relevant learning objectives for higher education professors on management of biorisks including deliberate disease risks? Examples for learning objectives of the instruction design plan of the research, with educators as learners population, come from the US National Academies of Sciences faculty development project on responsible conduct of research. The project's learning objectives for participating faculty members included: "develop a

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[354] This may include educational prerequisites, specific learning media, necessary laboratory equipment, etc.

[355] During the ISD workshop, participating faculty members from Country B HEIs argued that from their point of view "learning objectives" is a more proper definition for the point of view of the instructor ("what the teacher wants to teach"), while ILOs is really "what the designer wants the students to achieve". This is a meaningful point and in this perspective, "learning objectives" would derive from ILOs. However, for simplicity in the research I keep the consistent "learning objective" category from the ISD literature as explained above; and I would rather refer to "what the teacher wants to teach" with "instructional objectives".

teaching module to illustrate the use of the concepts of responsible conduct of research; identify the difference between chemical and biological hazards; be able to describe biosafety guidelines and standards of practice to prospective trainees; identify policies and guidelines and regulatory statements of both international and local bodies and critique the applicability of these statements; be able to write standards of practice for their own institution, department, or laboratory" (National Research Council, 2013 p. 113).[356]

6.1.4 Learning objectives for the education plan

In the ISD workshops with faculty members, participants were coached on designing learning objectives according to the above model and to an adapted matrix of levels and cognitive domains of learning (see Table 22). Thinking learning objectives in these terms is useful to Design objectives that are relevant, meaningful and achievable for the learner population and instruction context analysed; Develop and Implement appropriate educational materials in the subsequent ADDIE phases; and design correct evaluation methods.

For example, a learning objective such as "at the end of the Biosafety, Biosecurity and Bioethics course the student must state the definitions of biosafety, biosecurity and dual-use" could be categorized as a "knowledge; know" learning objective according to levels of learning and cognitive domains. Conversely, a learning objective where the student is required to "complete a biosafety and biosecurity risk assessment of a research project, including biological hazards and risk scenarios identification, risk characterization and risk evaluation" could be classified as a "knowledge; evaluate" objective. Finally, a learning objective such as "at the end of the Laboratory Techniques and Biorisk Management module, given a simple scenario, the student is able to find the correct PPE, don and doff[357] it in the correct order in less than five minutes" is a "skill; apply" type of objective.

[356] It should be noted that for what regards learning objectives in the education plan of the research, i.e. for the learner population of university students, the NAS project formulated what I would call instructional objectives rather than proper learning objectives (see the discussion above), as they included: "use a historical case study to engage students and deepen their awareness of the various issues; offer a problem and ask students to describe any obvious hazardous situations; critique and discuss how these [policies] apply to participants' own experience, laboratory, institution, or country".

[357] Contractions of "do on" and "do off", respectively, these verbs indicate the procedures to dress in and take off specific or technical clothing such as PPE.

An effective way to demonstrate the value of such categorization during design of learning objectives is to lead participants to think how different objectives would be linked to the following Development, Implementation and Evaluation ADDIE phases. Learning objectives have also to be based on what the learner needs and is able to achieve, and what is possible in the instructional context – all information available from Analysis.

Table 22 - Taxonomy of levels and domains of learning used in ISD workshops

Levels of Learning / Cognitive Domains				Cognitive domains		
				Knowledge (Know)	Attitude (Feel)	Skill (Do)
				Theoretical	Emotional	Practical
Level of Learning		Examples of action verbs				
Evaluate	Make value judgement; introduce innovations	Judge, assess, defend, predict, infer, argument	Higher, more complex, abstract, more critical thinking	*Knowledge; Evaluate*	*Attitude; Evaluate*	*Skill; Evaluate*
Analyse	Being able to further abstract, understand why, and transfer learning to other, different situations	Examine, compare, experiment		*Knowledge; Analyse*	*Attitude; Analyse*	*Skill; Analyse*
Apply	Transfer what understood to other similar situations	Use, perform, measure		*Knowledge; Apply*	*Attitude; Apply*	*Skill; Apply*
Understand	Process the meaning; being able to re-state	Explain, describe, recognize		*Knowledge; Understand*	*Attitude; Understand*	*Skill; Understand*
Know	Remember material in the same form	Define, list, memorize	Lower, simpler, factual, less critical thinking	*Knowledge; Know*	*Attitude; Know*	*Skill; Know*

While ISD workshops participants didn't achieve full mastery on designing learning objectives on biorisk management (as it will be further discussed in Chapter 9 on Evaluation in the instruction design plan), their exercises in designing learning objectives for students are a key result of this research. Faculty members from Country B for example defined learning objectives for students in each courses on biorisk management they drafted. Learning objectives (or, in Country B's nomenclature, ILOs) were grouped according to the categories of levels of learning used in Country B higher education system's translation of Bloom's Taxonomy.[358]

Examples of results from Region A, Country C and Country D participants are reported in Table 23, Table 24 and Table 25, respectively. Participants were asked to categorize the learning objectives they drafted under cognitive domains and learning levels, and to match them to the characterization of their students and instructional context.[359] Participants who focused on graduate student populations generally designed more complex or specific learning objectives; also, more advanced students generally are matched with learning objectives of higher levels of learning.

These exercises facilitated participants in assigning learning objectives relevant to different student populations, such as practical and/or "executer" learning objectives (for example of the Apply cognitive domain) to certain populations, and theoretical and/or "managerial" learning objectives (such as of the Understand or Evaluate cognitive domains) to other populations. Furthermore, the Analysis of the learning context and format, on the one side pushed participants to think what was needed to reach desired levels and domains; on the other side to consider if the teaching formats were feasible given class size and available infrastructures.

[358] Participants' definition of learning objectives could be improved but they already demonstrated consideration of the learning-by-design principle.

[359] Information in square brackets reports participants' categorization of the learning objectives they drafted by learning level and/or by cognitive domain, when it was indicated.

Table 23 - Examples of learning objectives matched with analysis by Region A participants

Code[360]	Title	Analysis					Design
		Student characterization	Context/Format				Learning Objectives
			Format	Hours	Prerequisites	Students	
DD.RA.13	Medical Waste Management	Bachelor of Environmental Health Sciences, 2nd Year.	Lectures, case studies, videos	22	Knowledge on microbiology.	30	Know the definitions and concepts related to medical wastes management; Know the categories of medical waste; Know the methods of collection, storage and treatment of medical wastes; Feel confident to manage medical wastes; Develop integrated waste management plans for laboratories and medical facilities.
DD.RA.05	Securing Field Collected Biological Materials without Unauthorized Access	Research assistant or graduate student working on an infectious diseases research project	Lecture; group discussion; practical activities on PPE, packaging, waste disposal	8	Bachelor in any biological science.	12	[Know] what methods are important for securing biological materials collected in the field; [Know] what methods can be used to securely and safely transport biological materials [Know] how to safeguard personnel, physical property and information; [Feel] confident that the right collection, labelling and transportation of biological materials during field work is applied. [Feel] comfortable in shipping samples in a secure way; Label, store and ship biological samples collected and/or being used in the field; Decide on the best method to use to secure project information, personnel and property in case of an emergency.
DD.RA.01	Bioethics in Biorisk Management and Outbreak investigation	Field epidemiology and laboratory management student; Master level first year.[361]	Lectures, brainstorming sessions, home assignments	4	Laboratory technician, medical doctor [or] program manager in diseases surveillance field. Know basics ethics principles.	30	[Know] expectations of laboratory ethical behaviour and proper conduct during outbreak investigation; [Know] what actions should be taken during ethical dilemmas both at work and in life; Feel ethically accountable for their own actions and that their actions reflect on the reputation of the institution; Identify potential concerns in own daily work as a field epidemiologist; Properly communicate or report issues where appropriate; Document and justify decisions as appropriate.

Table 24 - Examples of learning objectives matched with analysis from Country C participants

Code	Title	Analysis					Design
		Student characterization	Context/Format				Learning Objectives
			Format	Hours	Prerequisites	Students	
DD.C.01	Introduction to Biosafety Containment	Graduate Student in Life Sciences	Lectures integrating brainstorming; videos	2.5	Distinguish between risk and threat; Be able to characterize and	10	[Know] Introduction to biocontainment laboratory and design intent; [Know, Understand, Analyse the] difference between primary and secondary containment barriers; [Know, Understand] distinguish characteristics between different Biosafety Levels; [Understand, Analyse] identify different facility features; [Analyse, Understand, Evaluate] identify correct biosafety levels;

360 DD = design document; RA = Region A; C = Country C; D = Country D; the numbers identify the individual participant

361 Future tasks analysis: "responsible for outbreak investigation, confirmation and declaration. Also responsible for outbreak prevention and control and immediate response where outbreaks are suspected and confirmed."

					evaluate risk		[Analyse, Apply] recognize appropriate biosafety levels; [Apply] communicate with others and share the knowledge.
DD.C.05	Characterization of risk associated with working in the laboratory on biological hazards	Undergraduate student of Life Sciences (Biology)	Lectures; group discussions; simulations on mitigation strategies	3	Be aware of existence of biological hazards; realize the need for biorisk management; adhere to guidelines	10	[Know] list biological materials; [Understand] the consequences of biological hazards if identified; [Apply] [Feel] confident about the protocols; [Understand] perform the protocols; [Analyse] examine the risk associated

Table 25 - Examples of learning objectives matched with analysis from Country D participants

Code	Analysis				Design
	Student characterization	Context/Format			Learning Objectives
		Format	Duration	Students	
DD.D.01	Biology student (undergraduate)	Lectures and activities	15 weeks (15-30 hours)	30-50	Be aware of safety and security Know basic principles of biological waste disposal or treatment according to the risk
DD.D.03	Medical microbiology clinical biochemistry undergraduate student	Small group teaching	45 hours (15 theory, 30 practical, case study)	40	Know definitions of: BRM, dual use, bioethics, hazard and risk; good lab work practices; PPE; decontamination; waste disposal; laboratory biosecurity
DD.D.07	Undergraduate 2nd year student	Lectures, data show, lab experiments, reports	16 weeks; 2hours theory, 2 hours practice	35-50	Know meaning of biosafety and biosecurity; Learn differences between biorisk (biosafety and biosecurity); Feel confident in dealing with biorisk facts and accidents.
DD.D.09	Undergraduate Biotechnology student	Lectures, hand-out, seminars	-	50	Know biosafety and biosecurity definitions; Know what assessment is; Know mitigation measures.
DD.D.11	MSc Genetic Engineering student	Lectures, small groups discussions; class discussion	-	25	Apply/Analyse: Biorisk management; waste management, decontamination, disposal
DD.D.12	PhD Molecular Biology student	Seminars, small group discussion, demonstrations	-	16	Analyse and Evaluate: AMP; ethical issues

Learning objectives for students, as with other aspects of Design, depend on the local context, interests and priorities. However, we can draw some generic considerations. It makes sense to assign to some student populations learning objectives of the "know" or "understand" levels that focus on learning pre-assessed risks. However, other student populations should be assigned learning objectives advancing the risk-based approach rather than conventional approaches relying on prescription and "memorization of risk categories and levels"; these students will be expected to "apply", "analyse" and "evaluate". Besides being capable of "critical thinking that includes a thorough risk assessment" (Grainger and Turegeldiyeva, 2015), if students learn the principles of risk assessment and management, they are more likely to apply this critical skill in a range of cases, not just on deliberate disease risks and not just on biological risks management.

Education should include designed learning objectives on understanding the factors contributing to risk; how risk is always relative and why; and the importance of assessment before, and of performance after, as well as on risk mitigation. Generally, instruction on deliberate disease risks in higher education will design more generic learning objectives than training on deliberate disease risks for experienced professionals.[362] Also HEIs have an interest in considering the ethical components and implications of biosafety and biosecurity, including the issue of dual-use in relation to deliberate disease risks. Designed learning objectives for a higher education context would likely include the responsibilities of scientists or public health professionals in front of the community and society; responsibilities to take action to prevent unsafe or un-secure situations; and responsibilities to oversee the potential for misuse to cause harm, including managing the risks connected with dual-use.

6.2 Designing options for learner-centred education

Educational media selection is another Design aspect to consider. Clearly some learning objectives will need specific educational media; in particular, practical learning objectives will need practical activities and learning contexts. In general, learner-centred learning is more effective in achieving and retaining learning than traditional, instructor-centred learning, for any type of learning objective, at

[362] This may mean that learning objectives for university students will likely be lower in the taxonomy of learning levels; or they could be high level (up to critically "evaluate"), but looking at wider cases than the specific scenarios used for in-service training courses.

different levels of learning and in different cognitive domains, but especially in the sciences and regarding higher levels of learning and the cognitive domains besides knowledge (Colliver, 2000; National Research Council, 2000; Prince, 2004; Michael, 2006; Salas and Cannon-Bowers, 2001; Armbruster et al., 2009; Haak et al., 2011; Ruiz-Primo et al., 2011; S. Freeman et al., 2014).

However, in HEIs and especially in undergraduate, traditional instructor-centred learning is still the dominant mode in many countries (Halpern and Hakel, 2003). This implies that safety, security and risk management are largely taught in lectures. This has logistical reasons such as the size of classes of students, which may range from several dozens to hundreds, the absence of teaching time, and the lack of supplies like multimedia equipment. However, often the main challenges to introduction of learner-centred teaching in higher education are the lack of training on learner-centred techniques among teachers, a possible "business as usual" attitude on teaching styles, and the lack of instructional design in curricula.

Nonetheless, teaching management of biorisks, including deliberate disease risks, in higher education, implementing components of learner-centred techniques, and coping with the requirements and limitations of the structured higher education system, seems possible.

6.3 The design document tool

In order to support education Design in the education plan of the research, as well as to facilitate participants in becoming instructional designers in the instruction design plan, it is useful to have a structured tool that organizes results from the Analysis and Design decisions. Such a tool is the design document, compatible with what is suggested by ISD literature as well as with existing educational resources (Grainger and Turegeldiyeva, 2015).

ISD (Hodell, 2011) suggests a structure[363] for design documents that is meaningful from the point of view of a reader oriented to moving on to carry Development and Implementation. However, it is not the ideal order to *write* a design document. A designer should firstly describe the problem to address. Secondly, they should identify the broader requirements that the curriculum will

[363] Which starts with a rationale for the curriculum; then learning objective(s); description of target population; description of the curriculum including length, methods, materials needed, references; students' prerequisites; instructors' prerequisites; and evaluation strategy.

advance or contribute to: this may be connected with national, professional or international legal or regulatory requirements, and will become useful in relation to the organizational impact of education to be measured under Evaluation. It also pushes participants to think education in perspective of the strategic goal of reducing risk, and understanding that the reason for education is not learning *per se*.[364] Subsequently the description of the target student population should be completed, including assumptions as level, degree, specialization; prerequisites; and possibly tasks analysis. Designers should then think to the anticipated steps after education, that may include further training or application, to check and position instruction in a broader capacity building framework. This should be followed by the definition of the learning objectives using the criteria discussed before, and description of corresponding evaluation strategies. It is important that the planned evaluation strategies are strictly connected with the defined learning objectives, and that they are thought of before looking at formats, as they may influence them. A section on course description should include length and credits of the course. Next, a description of the instructional environment should include required qualifications for the instructor of the designed course, such as competences, training or certifications;[365] instructional environment conditions (supplies, materials, etc.); typical size of the class; delivery methods; references and educational resource materials. Finally, it is useful that the design document includes an agenda with topics, allocated time, instructional methods and existing or needed educational resource – this would be used during the Development phase to create or organize lesson plans and materials. An overview of design document examples developed by participants to ISD workshops from different projects is reported in Table 26. The depth and quality of education designs by participants varies. Possibly not surprisingly, the biggest struggles seem to be in drafting well-designed learning objectives and

[364] This is reinforced to participants to ISD workshops through learning activities that will be discussed in Chapter 7.

[365] An instructional designer could also be a course instructor, or design courses that will be developed and/or implemented by others.

corresponding Evaluation strategies, as will be further discussed in the next paragraph.[366]

[366] Also we noticed that when the evaluation strategy is kept at the end of the design document tool (as in the "reader" format), it is often just left blank. Moving that section up just after the learning objectives encourages making proposals that are specific and relevant to learning objectives. Another example of instructional design is from the TBL seminar format for life science students on deliberate disease risks used in some EUBARNet and Project 18 seminars. In that case, designed learning objectives were incorporated into a pre-designed course structure used for all subjects. Designed learning objectives included to "know what dual-use is"; "understand the risk/benefit components of the dual-use dilemma"; "evaluate recommendations on dual-use research management by the Fink and the Lemon-Relman reports"; and "explain the dual-use dilemma in own words". The TBL format will be discussed in more detail in Chapter 7.

Table 26 - Examples of completed design documents by participants to ISD workshops

Country	Country C	Region A	Country A University 2	Country B
Code[367]	DD.C.06	DD.RA.01	DD.A2.01	DD.B.01
Problem/Rationale/Aim/Overview[368]	[…] reinforce the importance and consequences of following a set of rules. Emphasize on decontamination […] and assess the risks involved […]. How proper practice in the lab makes the people in and around them safe.	Acting ethically and with integrity both during lab activities and on field outbreak investigation.	Enhance awareness of biorisk management tools	Biorisk and bioethics concepts are little known and with limited […] a basic course in this field is essential
Completion will help achieve these requirements		Protect the environment from likely contagious biological agents; protect all personnel […] due to lack of respect of ethics.		Teach […] basic principles of biorisk; train the student on basic requirements […]; transfer biorisk knowledge to the community.
	Learner Description			
Target Learner Description	Graduate student of Microbiology and Biotechnology	[Student of] College of Medicine […] Master level, Year 1. […]	Medical doctor; nurse; Pharmacist [student]	All undergraduate students in medical, life sciences, agriculture Faculties.
Learner prerequisites	Know[s] about risk and threat; […] basics of risk assessment and mitigation	[…] know[s] basics ethics principles in research; […] document[s] and justify decisions […]; understand[s] BRM terms		High School certificate
Anticipated next steps	Start practicing and implementing; discuss with colleagues and batch-mates	[…] assessments as stipulated in […] academic regulations; draft a bioethics guideline adapted to their work settings; sensitization session […] for all the staff they work with […]		[…] participate in biorisk mitigation and […] spread the culture of biorisk management among the community.
	Learning Objectives[369]			
Knowledge[370]	[Know] good laboratory practices; [Know] categorize the various biosafety levels and cabinets; [Understand] decontamination strategies; [Know] various types of PPE; [Understand] different dual-use	[Know] expectations of laboratory ethical behaviour and proper conduct during outbreak investigation; [Know] what actions should be taken during ethical dilemmas both at work and in life.	[Know] terminology: Biorisk, Biosafety, Biosecurity and Dual-Use Dilemma	Understand basic concepts of biorisk, including theories, principles and rules; Analyse situations related to biorisk and evaluate biorisk impacts.

[367] DD = design document; C = Country C; RA = Region A; A2= Country A University 2; B = Country B; the numbers identify the individual participants

[368] Note how these are in some cases formulated as instructional objectives

[369] Action verbs from our version of the Bloom's taxonomy (see Table 22) are added in square brackets when not explicitly categorized by instructional designers.

[370] Including Know/Know and Understand/Intellectual Skills in nomenclatures in different countries/regions

	material found in the lab […]			
Attitude[371]		[Understand] feel ethically accountable for their own actions and that their actions reflect on the reputation of the institution; [Apply] capable of identifying and resolving ethical dilemmas.	[Know] ethical conduct; apply the AMP model.	[Apply] Communicate professionally with the community.
Skill[372]	[Apply/Analyse] follow Good Laboratory Practices: [Apply/Analyse] use proper PPE; [Analyse/Evaluate] assess methods of decontamination, decontaminate.	[Understand] Identify potential concerns in own daily work […]; [Apply] Properly communicate or report issues where appropriate; [Analyse/Evaluate] Document and justify decisions […]		[Apply] Act efficiently towards biorisk issues.
	Evaluation Strategy			
Level 1 (Reaction)	Group discussion among the students; feedback forms.	Number of students who complete the course; Students will complete a satisfaction questionnaire […].	Practical Exercises	
Level 2 (Learning)	[Student] can define biosafety, biosecurity, decontamination, disinfection, and sterilization; classify organisms […] [Student] knows [their] PPE, can segregate material based on the hazards […].	Students will produce adapted drafts of code of conducts related to their working areas […]	Examination	Evaluation will be based mainly, on written exams. Also participation, observational and practical skills, assignments, and reporting will be considered.[373]
Level 3 (Behaviour)	[…] how the student handles the laboratory instruments	Three months after the training, […] check whether bioethics principles are complied with […]	Questionnaires	
Level 4 (Result)	[…] test before admissions	Review of the annual reports about incidents in lab […] from various facilities to the line Ministries […]	Audits of SOPs, Incident reports, etc.	Change in biorisk policies and internal regulations.
	Course Description & Instructional Environment			
Total duration	8 hours	4 hours	15 hours	8 hours
Instructor's prerequisites	Doctoral student; [completed] course on Biorisk Management and Mitigation	Instructor must have completed the GBRMC orientation […]. He/she also need[s] to be hired […] as a Faculty.		
Number of Students	20	30	150	25-50
Delivery (teaching) techniques	Show how to don and doff PPE; what areas of the lab/work bench should be decontaminated, checked after use; who is a good lab work practictioner? Demonstrate how he/she works in the	Brainstorming sessions about ethics on biological agents and toxins (group discussion […]). Take-home assignments about adapting their ethical guidelines to their respective work settings	[Group] activity, tutorial	Practical applications in lab. Field visits to […]

371 Including Feel/Communication and Transferable Skills in nomenclatures in different countries/regions.

372 Including Do/Professional and Practical Skills in nomenclatures in different countries/regions.

373 "Grading is based on 50 marks […] distributed as follows: 30 for final exams (theoretical 20 and practical 10), 15 for midterm exams (theoretical 10 and practical 5), and 5 for assignments, reports, and participation."

	lab.			
References, educational resources, bibliography	GBRMC; WHO Guidelines	GBRMC; […] the Nuremberg Code; CITI Programme; *On Being a Scientist*; UNESCO Universal Declaration of Bioethics and Human Rights; IAP 2005 guidelines on codes of conduct	Existing course's curriculum; […] Guidelines for Biosafety in Teaching Laboratories (ASM); WHO (Responsible Life Science Research for Global Health Security; Laboratory Biosecurity Guidance); GBRMC	WHO Biosafety Manual

6.4 Designing evaluation

While it may seem surprising that a part on instruction Evaluation is included in the Design phase, this should make sense following the learning-by-design pillar. It is indeed crucial that Evaluation is planned during Design and closely linked with learning objectives.

Evaluation of education on deliberate disease risks follows the model of the four levels described in Chapter 2. While *measuring* evaluation takes place after implementation, and from Level 1 (Reaction) to Level 4 (Results), *design* of evaluation happens backwards and is planned before implementation. Desired objectives for each Level are based on how they contribute to achieve the next Level. First, Level 4 objectives have to be identified. In our case, Results objectives are lowering the risks of deliberate disease, by lowering their likelihood and/or consequences. Level 3 (Behaviour) objectives have to be identified as those behaviours, which, if retained and/or generalized, have the potential to lower the risk likelihood and/or consequence. Level 2 (Learning) objectives represent the learning, which, if achieved and transposed in regular practice, have the potential to become behaviour.[374] Finally, Level 1 (Reaction) objectives correspond to the satisfaction needed to allow learning. As the model goes, if evaluation design is correct, students' satisfaction would create the conditions for learning; students would achieve desired learning in appropriate levels and cognitive domains; learning transposed to regular practice and sustained over time would become behaviour; sustained and generalized behaviour would contribute to a situation with lower risk likelihood and/or consequence.

Evaluating performance directly is often complicated or even impossible. It may require, for example, continuously checking learning on all possible knowledge, attitudes and skills, or a pervasive monitoring of behaviours. Representing, communicating and comparing these measures would also be challenging. Indicators should rather be used, which "indicate" what is happening: instruction designers plan on what indicator(s) would give a meaningful indication of the extent of actual learning, behaviour, and impact. The ideal format for learning objectives is particularly useful as it also represents a format for Level 2 indicators. The second key component of an evaluation design is metrics, or

[374] And they are exactly the learning objectives we have discussed earlier in this Chapter.

how the indicator will be measured. Finally, the Evaluation design has to plan how, where and/or when to collect the data for the metrics to measure the indicators.[375] In the examples of four-Levels evaluation strategies from ISD workshops participants' design documents exercises reported in Table 27, it could be noted how some participants mixed, or only provided some among, indicators, metrics and data collection tools.

Based on suggestions from Design Documents, as well as on the multi-year experience of instruction design on deliberate disease risks education, I propose matrixes of four-Levels as possible evaluation tools for education as a potential deliberate disease risks mitigation measure. These matrixes could be used to measure the education's results on the risks of deliberate disease, as well as of instruction design programs for such education, i.e. the two plans of research we consider.

6.4.1 Design evaluation for the education plan

Table 27 reports the proposed evaluation matrix for the education plan of research. Learning, behaviour and results indicators have been grouped in four thematic areas whose mastery may be relevant in influencing likelihood and/or consequences of deliberate disease risks in the three risk scenarios described in Chapter 3. The (bio)risk management area would include capacities on understanding the nature and components of risks, assessing risk and taking risk-informed management decisions, that have the potential to influence risk in the three reference scenarios. The laboratory biosafety area includes capacities on preventing accidental and unintentional harm in the laboratory.[376] These capacities may have the potential to limit risk in the second scenario, as they would mitigate the possibility that a biosafety risk evolves into a biosecurity risk (for example because a non-state threat without access to assets, gains access because of inadvertent release). However, this potential influence would only be indirect and capacities in the laboratory biosafety area would mainly impact other biorisks than deliberate disease risks.[377] The third area includes

[375] For each metric the designer can also plan a threshold that will make the educational action "successful" for that indicator, or just plan on observing results.

[376] Such as laboratory acquired infection; contamination; pathogen release in the environment.

[377] Though not the primary aim of this research, it's still useful to consider them firstly to integrate the evaluation design and secondly because many of the capacities for biosafety and biosecurity reinforce each other.

capacities on laboratory biosecurity, and would be particularly relevant to mitigate deliberate disease risks under the second (non-state threats seeking access to assets and/or capabilities) and third (non-state threats with access to assets and/or capabilities) considered deliberate disease risk scenarios. The fourth area includes capacities related with biosecurity and dual-use management broader than the laboratory approach; these capacities have the potential to influence deliberate disease risks under all three deliberate disease risk scenarios.

The first Level of Evaluation, Reaction, "measures how those who participate in the program react to it" (Kirkpatrick and Kirkpatrick, 2006 p. 21). Level one Evaluation is important for the instructors to know how students feel about the program, and for the students to know the instructors care about their opinion (Kirkpatrick 2007). Measuring this Level does not really depend on the subject matter, and indeed proposed strategies are the same for all four thematic areas. However, it is important that Evaluation is planned, even if methods do not need to be highly structured (Kirkpatrick, 1979), and can include data points as simple as students' participation, their use of class materials, etc. Our designed indicator for Reaction is if and how students are satisfied, interested, and/or engaged by the instruction experience. Meters (i.e. metrics) of such satisfaction can include attendance of classes and feedback from students;[378] but also if and how much students actively participate in activities; interact with the instructor with questions; express positive comments. Data collection methods for those metrics may include attendance sheets; satisfaction surveys or "smile sheets"; observation by the instructor; number of questions raised in class or on an e-learning forum; information collected to a group activity; follow-up communications with students.

Evaluation at the second Level, Learning, looks at if the student achieved the learning objectives designed for them. The indicators of Learning are the learning objectives categorized according to the cognitive domain of knowledge, attitudes and skills; and to the levels of learning such as know; understand; apply; analyse; and evaluate. A careful Design of learning objectives makes it

[378] The metrics can measure, using for example data from satisfaction surveys, the average appreciation from students and/or the share of students who appreciated. The choice largely depends if instructor value evaluating the enthusiasm ("level of satisfaction") or that all students in the class have a minimal satisfaction ("spread of satisfaction"), or both.

easier to design appropriate metrics and data for their evaluation. Level 2 indicators in the matrix have been designed based on my and others' experience in teaching on biorisks, and deliberate disease risks particularly; learning objectives drafted by faculty members participating to ISD workshops; and learning objectives from several existing educational materials, primarily the GBRMC and the ERM. Those included in the proposed matrix do not cover all possible Learning indicators.[379] However, they are a meaningful collection and examples of Learning indicators that could be designed backwards from Level 4 and Level 3 objectives.

Evaluation at Level 3 looks at specific behaviours that would be expected if the learning on Level 2 is not only achieved but also translated to normal practice and sustained over time.[380] Those specific behaviours are designed based on what would be needed in the hypothesis to influence risk factors, such as assess risks, develop and implement plans; maintain control over hazardous material; respond to incidents; or dissuade personnel with knowledge from theft, loss or misuse of pathogens (Young et al., 2014). The passage from Level 2 to Level 3 evaluation is crucial in the higher education context and was particularly stressed in the ISD workshops with professors. Indeed, HEIs and educators generally have extensive experience in evaluating Level 1 and Level 2, but may lack opportunities to go further.[381] Learning is a necessary condition for behaviour, as "if little or no learning has taken place, little or no change in behaviour can be expected" (Kirkpatrick and Kirkpatrick, 2006 p. 60). However,

[379] As they are not all potentially useful or necessary learning objectives on deliberate disease risks and other biorisks management for public health, life sciences and technology, medicine or veterinary higher education students.

[380] The third level of evaluation tries to answer questions such as "did the training stick? How much of the training transferred from delivery to the workplace?" (Hodell, 2011 p. 74). Another definition of Level three could be "achieving behavioral generalization (i.e. applying the skill outside of the training simulation)" (Salas and Cannon-Bowers, 2001 p. 485). The transfer from Level two to Level three is sometimes overlooked in teaching, however "we only care about student performance in school because we believe that it predicts what students will remember and do when they are somewhere else at some other time … if we want transfer, we need to teach in ways that actually enhance the probabilities of transfer. The purpose of formal education is transfer"; and it has an impact on teaching design as "teaching for retention during a single academic term to prepare students for an assessment that will be given to them in the same context in which the learning occurs is very different from teaching for long-term retention and transfer" (Halpern and Hakel, 2003 p. 38).

[381] In some cases this is because they are not able to follow students' instruction or professional paths, or it may also be due to a lack of perspective on the ultimate goal of education beyond learning per se.

university educators can relate with examples of cases when achieved Level 2 indicators do not translate in Level 3 ones: such as students who pass courses' final tests, demonstrate abilities in a mentored session, but months later do not remember the same notions, or do not keep the learned practice in their laboratory or research behaviour.[382] Learning is a necessary but insufficient condition for behaviour, so Level 3 needs to be evaluated specifically.[383]

Evaluation at Level 4 in general looks at the broader results of education. In this research it looks at factors influencing likelihood and/or consequences of deliberate disease risks, in the three deliberate disease risk scenarios. These factors should be influenced by a generalized, sustained and formalized adoption of behaviours from Level 3. Indicators at this Level will be connected to risk likelihood or consequence factors of hazards, threats or situation for deliberate disease risks. Examples of indicators from relevant studies looking at different Level four impacts include increased range of service delivery, improvements of clinical care, being involved in teaching, training, committees, international collaborations, co-author peer reviewed articles or books (Anderson et al., 2014); herd productivity and fertility (Knight-Jones and Rushton, 2013); or economic value added by the training (Buganza et al., 2013). Specifically for the context of higher education, it has been suggested that Level four should evaluate how those educated by HEIs would contribute to society, proposing indicators such as qualifications, socialization, subjectification (or how students have developed independent thinking) (Praslova, 2010), students' character development and ethical readiness for their roles in society (Boyer and Hechinger, 1981; Sax, 2004).

Correspondence between indicators in the four Levels is not 1:1, and they diminish raising Levels. Multiple learning objectives concur in nurture or modify a behaviour, and multiple behaviours may influence a risk factor. In case of specific or particularly important competences, one learning objective may correspond to one behaviour and one Level 4 goal.

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[382] Reasons for learning not translating to behaviour could vary, and include for example different equipment; complacency; or poorly designed learning objectives. In any case, translation from learning to behaviour is not granted at all, hence why Level 3 should be measured.

[383] It should also be noted that environmental factors may have a role in moderating the translation from learning to behaviour, such as commitments of hierarchy, opportunity, support from peers, and work context (Salas and Cannon-Bowers, 2001; Bates, 2004; Kontoghiorghes, 2004).

6.4.1.1 Indicators, metrics and data

In the risk management area, knowledge Learning indicators include for example the capacity to define risk; distinguish between biosafety and biosecurity; and prepare a biorisk assessment. An attitude indicator is that the student feels confident in using a biorisk management approach, based on assessment, mitigation and performance. Level 3 indicators[384] include that students prepare actual risk assessments. In the laboratory biosafety area, theoretical learning indicators include the hierarchy of mitigation measures or types of PPE; practical learning indicators include donning and doffing PPE and washing hands. Behaviour indicators include that students continue to appropriately select mitigation measures, wash hands, or do not eat and drink in the laboratory. Proposed Level 4 indicators look at laboratory or hospital acquired infections, environmental releases, and cross-contaminated samples. In the laboratory biosecurity area, examples of Level 2 indicators include knowing different measures within the pillars of physical security, personnel management, material control and accountability, transport security and information security; while practical indicators include being able to apply those measures, such as securely labelling packages or protecting information. Level 3 indicators examples include the extent to which participants changed their behaviours and applied learning to their usual work (Buganza et al., 2013), such as when physical security is considered in laboratory design or commissioning projects; or that the chain of custody of assets is maintained. Result indicators may include breaches, thefts, and losses of assets. Finally, in the biosecurity and dual-use management area, proposed Level 2 indicators include knowing experiments of concern and options to manage potential misuse; feel responsibilities deriving from dual-use issues; or being able to document decisions on dual-use as appropriate. For all thematic areas, I designed examples of learning objectives (and Level 2 indicators) not least based on input from the professors interviewed who have been involved for a number of years in promoting education on deliberate disease risks, but this is particularly true for the dual-use and broader biosecurity thematic area. So the idea of introducing learning objectives constructed in the knowledge and attitude cognitive domains and ranging from the simplest “know” level to the more

[384] Level three indicators are also sometimes referred to as “transfer criteria” (Alliger et al., 1997).

advanced "analyse" or even "evaluate" levels of learning[385] complies with what is suggested, for example, by Professors 1, 4 and 9:

GMM: "what do you want them to know at the end of the course, and be able to do at the end of that course?

Professor 1: at the beginning, that they are aware of this problem of dual-use. It is necessary that they are aware, because clearly they are not. This is the first thing, raising awareness. Then, that they understand the danger…for society. Of this problem, this dual-use"[386]

GMM: "so the goal was being aware?

Professor 4: no, it's very well defined […] how you define that? Because you know, raising awareness it's just too… fuzzy, right? So you have to work an… ok… we introduced an ethical theory, we show that we trained them in argument, arguments, and you know in case, case system and so on, and again we had to have the students themselves to express in essays or in self assessment, 'do I know enough about this', to argue, or 'do I know enough about ethical theory' to really, you know, use valuable arguments in a discussion and so on…"

Professor 9: "regarding to… what is the ideal competence that… I would like to achieve… it would be, that when confronted with a case, they would be able to… understand it, interpret it, or react to it […]"[387]

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[385] The discussion on the different levels of learning related to learning objectives, on dual-use, and relative challenges, is discussed in Chapter 8 on Evaluation in the education plan.

[386] Translated from the original French: "*Professor 1: d'abord, qu'ils soit sensibles de que ce problème du double usage. Il faut qu'ils soit sensibles, parce-que nécessairement ils ne sont pas sensibles à ça. Ça c'est la première chose, sensibilisation. En suite, qu'ils comprennent le danger… pour la société. De ce problème, ce double usage".*

[387] Translated from the original Italian: "*Professor 9: rispetto a… qual è la competenza ideale che… mi piacerebbe poter raggiungere… sarebbe davanti a un determinato caso, che loro fossero in grado di… capirlo, di interpretarlo, o di reagire […]".*

Proposed Behaviour indicators in this thematic area are if students contribute to the development of oversight or other management and decision-making systems on dual-use; or reporting practices on managing dual-use material, equipment and information.

Metrics can be more or less formal. At Level 2,[388] quite informal tools may include observation, opinions of facilitators after interaction with students, and exercises completed during the curriculum. In some cases, Evaluation can be completed with self-assessment tools.[389] In some cases, however, an informal and/or self-assessed evaluation may not be enough; this will depend on the “degree” component designed into the learning objectives. Some training may need a rigorous, defined and formal evaluation method and threshold (“passmark”). In the higher education context, formal evaluation is usually a requirement for curricula,[390] sometimes requiring formal pre- and post-tests (Arthur Jr et al., 2003). Appropriate metrics should also be planned with the cognitive domain in mind. For Learning indicators, proposed metrics use benchmark or reference definitions and minimal performance requirements. For know, and for some attitude, objectives possible data tools include instruction paper-and-pencil tests (Kirkpatrick and Kirkpatrick, 2007) in the form of multiple choice questions, logical sequences, statement corrections, quizzes; peer evaluation among students; matching exercises; class discussions; exercises based on scenarios or case-studies; essay writing; and presentations by students (Praslova, 2010). Data tools for practical learning objectives include simulation, drills, role-playing (Kirkpatrick and Kirkpatrick, 2007), or communication exercises. Metrics for Level three indicators can include ratings from supervisors or job outputs. Specifically for higher education, it has been suggested that metrics for indicators should include “evidence of student use of knowledge and skills learned in previously taken classes in their following class work, including research projects or creative productions, in application of learning during internship, and in other behaviours outside the context in which the initial learning occurred” (Praslova, 2010 p. 221). Typical data tools for Level

[388] Level two indicators are also sometimes referred to as “learning criteria” (Praslova, 2010).

[389] Which may be an important option especially for adult learners (Kidd, 1974; Knowles, 1984; Kirkpatrick and Kirkpatrick, 2007).

[390] Furthermore, some ISD workshops participants argued that if a course is not formally evaluated, it could not be included in the syllabus and/or students and other faculty members would not take it “seriously”.

3 evaluation include surveys, interviews (with students or educators), visits, reports (including from alumni's work supervisors), checklists, focus groups, Behavioural Observation Data (BOD) (Kirkpatrick and Kirkpatrick, 2007). Also for Level three, it is suggested that indicators could be measured before and after the training (Steensma and Groeneveld, 2010). While this is not always possible, it seems desirable that Level three indicators are measured some time after the training.[391] Indeed this is in line with experiences or aspirations of interviewed professors, who indicate post-instruction direct behavioural observation of students or cooperation with employers of former students as strategies to measure Level 3 indicators:

> *GMM: "… and, how would you see that… how would you assess that, at the end of that course?*
>
> *Professor 6: because… I think that if you watch them, if you are there with the students and it's your department, you watch them work… you know what they are doing, I have to tell them, 'ok you have a place, why are you eating in the lab?'. That means they are not…*
>
> *GMM: yes, that's a good example, eating in the laboratory*
>
> *Professor 6: … yes, initially we were not saying them anything because we didn't have a place. But now that we have a place, now I can question them.*
>
> *GMM: yeah, there's no excuse.*
>
> *Professor 6: ok? No excuse. So that means they have not still… you know, gone by the rules […]"*
>
> *GMM: "how will you look, how will you evaluate if their behaviour is actually following good practices ?*

[391] Kirkpatrick and Kirkpatrick (2007) suggest that Level three evaluation could be immediately after training courses, with instructors observing behaviour and correcting it, if necessary, as immediate reinforcement. I believe this would actually still be a Level two evaluation. With Level three, we should really focus on if the learning objective (knowledge, attitude, skill) sustains as situations change and time passes.

Professor 2: […] so, students will be in a network and we will actually plan so that they are followed. So this will follow them, via all channels, telephone, mail and all, until after their Master and see what's coming from it […] I am approaching the private sector. So the laboratories that organize, to tell them, look, we have trained competencies, you can see it too, and you need them… well, because of national, international recommendations, you… and the laws… you need, it's mandatory to have, and so that's it, and this is part of their system, the system of business, of certifications, so they need these people."[392]

Metrics for Level 4 can be qualitative or quantitative, depending on the indicator and how it has been designed, and useful data tools include samples of academic accomplishments, awards (Praslova, 2010); incident reports, publicly available information, alumni records, internal and external audits, surveys, and interviews.

[392] Translated from the original French: *Professor 2: […] Donc, ça, les étudiants vont être en réseau et on va même mettre à système pour que ils sont suivi. Donc on va les suivre, pour touts les moyens, téléphone, mail et tout, jusqu'à après leur Master et voir qu'est que ce vient […] je vais approcher le privé. Donc et les laboratoires qu'organisent, pour dire, voilà, nous avons formé des compétences, vous pouvez voir avec nous, et vous avez besoin d'avoir… bon, par les recommandations nationales, internationales, vous avez… et les lois… vous avez besoin, obligatoire d'avoir, et donc voilà, et ça fait partie de leur système de, le système d'entreprendre, des certifications, donc ils ont besoin de ces gents là.*

Table 27 - Four-levels evaluation matrix in the education plan

	L1 Reaction			L2 Learning			L3 Behaviour			L4 Result		
	Indicators	Metric	Data	Indicators (Domain: Level)	Metric	Data	Indicators	Metric	Data	Indicators	Metric	Data
Education plan of research. Learner population: students in public health, life sciences and technology, human or veterinary medicine												
Risk Management	The student is satisfied, interested and engaged	≥4,5/5 average evaluation	Post-instruction survey	Knowledge: Know: define the AMP model	The student provides a definition of the AMP model that includes assessment, mitigation and performance	Multiple choice questions; self-assessments; case study; statement correction; essay writing; class discussion; peer review; quizzes	Continuing to look at: possible risk scenarios (including what changed); risk likelihood and consequences	One month/one year/three years after training ≥70% of trainees retained and applied what learned	Surveys; interviews; visits (planned or surprise); reports from supervisors	Available biosafety and biosecurity risk mitigation measures	%	Annual biorisk assessment; incident reports; audits
		≥90% participants evaluating positively		Knowledge: Know: define risk	The student provides a definition of risk that includes: adverse event; likelihood; consequence							
		All groups participate (notes from learning activities)	Posters from learning activities	Knowledge: Know: factors that influence risk likelihood and consequence	The student lists at least five factors; and matches them with likelihood and/or consequence							
		Appreciations, suggestions, and/or asking for additional trainings	Follow-up communications; letters; post-instruction survey	Knowledge: Know: define biosafety and biosecurity	The student provides definitions that at least include accidental vs intentional (and/or hazard vs threat)		Consideration of biosecurity risks increased; communication lines with law enforcement (where relevant) established			Vulnerability. opportunities available to threats	Qualitative	
		% attendance	Turnout at the event; attendance sheets	Knowledge: Analyse/Evaluate: assess biorisk (characterization and evaluation)	The student demonstrates risk assessment (characterization and evaluation) in own laboratory or setting, given a scenario		Actual risk assessment prepared for own institute/context			Reviewed risk assessment	Yes/No	
		Student asks questions	Active participation during training; forums; observation	Attitude: Understand: feel confident about using the biorisk management approach	The student describes a biorisk management process starting from hazard identification within risk assessment, then mentions mitigation, and performance evaluation and review.							
Laboratory Biosafety	The student is satisfied,	≥4,5/5 average evaluation	Post-instruction survey	Knowledge: Know: hierarchy of laboratory biosafety controls	The student orders from the most to the least effective: elimination; engineering controls;	Multiple choice questions; self-	Applying the highest appropriate mitigation measure;	As soon as possible when student starts lab/field	Behavioural Observation Data;	Reduced laboratory/hospital acquired infections;	Year-over-year numbe	Incident reports; audits; publicly

	intereste d and engaged	≥90% participants evaluating positively			administrative controls; practices and procedures; PPE	assessments; case study; statement correction; essay writing; class discussion; peer review; quizzes	select mitigation measures according to route of exposure	work at university; Two years after graduation	SOPs developed by students; follow-up surveys	reduced cross-contamination of samples; reduced cases of environmental release.	r	available information; annual documentatio n
		All students participate (notes from learning activities)	Posters from learning activities	Knowledge: Apply: mitigation measures are based on risk assessment	The student selects mitigation measures after assessment; explains appropriateness of measure with risk.							
				Knowledge: Understand: advantages and disadvantages of laboratory biosafety controls	The student provides information such as: elimination is effective but not always possible; engineering controls are expensive, need maintenance; administrative controls are based on authority; practices and procedures on human factors; PPE only protect worker, difficult to operate							
		Appreciations, suggestions, and/or asking for additional trainings	Follow-up communicatio ns; letters; post-instruction survey	Knowledge: Know: decontamination, sterilization, disinfection	The student gives definitions of decontamination (remove contamination; rendering reasonably acceptable risk of disease transmission), sterilization (destroys or eliminates all forms of life, categorically and absolutely); disinfection (elimination of nearly all recognized pathogenic microorganisms).		Proper labelling of samples					
		% attendance	Turnout at the event; attendance sheets	Knowledge: Understand: recognize safe and unsafe work practices	The student distinguishes good and bad laboratory work practices		Separation between samples and food/drink in fridges					
							No eating, drinking, smoking in the lab					
		Student asks questions	Active participation during training;	Skill: Understand: washing hands correctly	During simulation, the student washes hands leaving no residues	Simulations; practical exercises; role-play	Washing hands properly and when required					

			forums; observation	Knowledge: Apply select PPE	The student correctly matches types of PPE with simple scenarios, based on routes of infection	exercise; poster design; write an SOP; peer review	SOPs involving PPE are developed					
				Skill: Understand: don and doff PPE	The student can don and doff in the correct order and at the first try: coverall, gloves, foot protection, respiratory mask							
				Skill: Apply: classify and segregate biological waste	The student matches wastes with categories (solid, liquid, sharps, pathological)							
				Skill: Evaluate: evaluate appropriateness of operational, facility and management risk mitigation measures	For each provided example, the student explains how the associated biological risk could be reduced		Laboratory biosafety considerations are integrated in work presented at scientific conferences	Occurrences, quantity and quality of consideration	Surveys; interviews; events' programmes			
Laboratory Biosecurity	The student is satisfied, intereste d and engaged	≥4,5/5 average evaluation	Post-instruction survey	Knowledge: Understand: importance and rationale of laboratory biosecurity	The student is aware that deliberate disease risks exist.	Multiple choice questions; self-assessments; case study; statement correction; essay writing; class discussion; peer review; quizzes	Biosecurity is considered in decision processes like lab design, procurement, etc.			Breaches/thefts reduced; loss of access (keys, locks, etc) mitigated; staff more confident and feel more secure		
		≥90% participants evaluating positively										
		All students participate (notes from learning activities)	Posters from learning activities									
				Knowledge: Analyse/Evaluate: complete a biosecurity risk assessment	The student is able to identify, characterize specific biosecurity risks and related threats, assets, and vulnerabilities, and evaluate risks based on personal and institutional preferences		Documented biosecurity risk assessment process regularly carried out and revised				Year-over-year N	Incident reports; audits; publicly available information; annual documentatio n
		Appreciations, suggestions, and/or asking for additional trainings	Follow-up communicatio ns; letters; post-instruction survey				Laboratory biosecurity considerations integrated in work presented at conferences	Occurrences, quantity and quality of consideration	Surveys; interviews; events' programmes			
				Knowledge: Know: methods for establishing physical security	The student lists at least three examples of methods for physical security		Different/new physical security methods considered in physical security decisions; physical security included in new design/commissioning					
				Skill: Apply: use information protection	The student demonstrates use of unique user IDs,		Protect personal password(s); do not		Behavioural Observation			

		% attendance	Turnout at the event; attendance sheets	methods	passwords and encryption as appropriate.		exchange users; change passwords regularly		Data (BOD); follow-up surveys			
		Student asks questions	Active participation during training; forums; observation									
Dual-Use and Broader Biosecurity	The student is satisfied, interested and engaged	≥4,5/5 average evaluation	Post-instruction survey	Knowledge: Know: the prohibition norm on deliberate disease	The student mentions the prohibition on deliberate disease from legal or ethical, national or international, sources.	Multiple choice questions	The students looks for more information		Behavioural Observation Data (BOD); follow-up surveys	A well established "norm" of not doing, not helping, and preventing, the misuse of life/health sciences to cause harm (weapons)	Cases	Follow-up surveys
		≥90% participants evaluating positively										
		All students participate (notes from learning activities)	Posters from learning activities	Knowledge: Understand: identify potential dual-use and broader biosecurity issues	The student provides a definition that at least includes that peaceful research, material, equipment or information can be misapplied to cause harm; and/or explains the criteria to recognize dual-use or potential misuse issues	Multiple choice questions; essay writing; review of research/work proposals and reports	Questions to instructors or supervisors on existing considerations in programs and systems					
		Appreciations, suggestions, and/or asking for additional trainings	Follow-up communications; letters of praise; post-instruction survey	Knowledge: Know: actions to take when faced with a potential misuse ethical dilemma	The student explains the institutional procedure to report an identified dual-use or potential misuse issue.		Questions on dual-use potential of material, equipment or information					
		% attendance	Turnout at the event; attendance sheets	Knowledge: Apply/Analyse: options to manage dual-use and broader biosecurity issues			Demands for an oversight system					
		Student asks questions	Active participation during training; forums; observation	Attitude: Understand/Apply: be aware of the responsibilities on dual-use and broader biosecurity and feel ethically accountable	The student discusses oversight and decision-making options on dual-use and broader biosecurity.		Documented decisions on dual-use issues; the student participates to the establishment of a Code of Conduct					

				Knowledge: Analyse/Evaluate: Document and justify decisions as appropriate			Integration of considerations on dual-use in work presented at conferences	Occurrences, quantity and quality of consideration	Surveys; interviews; events' programmes				

6.4.2 Design evaluation for the instruction design plan

Table 28 reports the designed evaluation matrix for the instruction design plan of research. In this case, the learner population are educators from public health, life sciences and technologies, human or veterinary medicine HEIs who participate to train-the-trainer ISD workshops and programmes to promote and implement education on deliberate disease risks. In the table and below we refer to learners as participants to distinguish them in this role from that of educators; and from learners in the education plan of research ("students").

It should not be a surprise that Level 1 evaluation is the same as the four subject matter areas under the education plan of research; as we have mentioned, Reaction evaluation doesn't really depend on the topic of instruction as it precedes it. We hence reprise the same indicators, metrics and data tools that have been proposed in Table 27. The second Level should evaluate if participants achieved learning on designing and promoting education, and follows competences on the ADDIE phases. Indicators include understanding what to consider characterizing learners and instructional components (Analysis); knowing components of the training design cycle and draft learning objectives (Design); preparing educational materials that employ principles of learning-by-design and learner-centred education (Development); deliver instruction applying techniques and methods (Implementation); and evaluate education (Evaluation). Metrics are proposed for each of these Learning indicators. Data on this Level can be collected from post-workshops evaluations; design documents drafted by participants; peer review among participants on educational materials and teach-backs; or observation during workshop activities.

Two Behaviour indicators are proposed that could derive from achieved learning, and could be prerequisites for a Result on education on deliberate disease: that participants apply what learned into teaching deliberate disease risks education to their students, implementing the pillars of learning-by-design and learner-centred teaching, and leveraging educational resources made available by subject-matter experts; and that participants further develop via attending and completing more advanced training on deliberate disease risks and/or instructional design on deliberate disease risks.[393] Data sources for these

[393] This approach is in line with the composite indicator of "Return on Relationships" proposed by Fair et al. (2016) to evaluate a cooperative engagement program. The metric for this indicator is based on a

indicators are similar to those from situational analyses described in the previous Chapter; questionnaire surveys; HEIs' syllabi; as well as interviews with participants.

However, the change in behaviour by participants doesn't necessarily imply an organizational change in the higher education instructional offer; specifically, as it depends on individual initiatives, it does not guarantee that education will be imparted to all students, credited with formal requirements, and embedded in the technical formation. We propose only one indicator for Level four (Result) that education on deliberate disease risks is institutionalized in HEIs, i.e. recognized at a higher and independent level than the behaviour of individual faculty members.[394] Metrics include that designed education is formalized, possibly with credits, made a requirement for degree completion or for professional abilitation, does not entirely depend on the choice of individual educator(s), and/or relevant learning objectives are documented in the educational program design.

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weighted sum of stakeholders engaged and deliverables produced, including publications/posters, conferences and curriculum. However, the weighting, which should be based on an "intangible value" in such metric is not clear, and I prefer to propose simpler metrics.

[394] It should be noted that institutionalization, in the form for example of accreditation, has also been suggested as a driver for improved learning outcomes: "evidence of a connection between changes in accreditation and the subsequent improvement of programs, curricula, teaching, and learning", (Volkwein et al., 2006 p. 277). In this sense, Level four indicators in the instruction design plan could also predict Level two achievements in the education plan.

Table 28 - Four-levels evaluation matrix on the instruction design plan

	L1 Reaction			L2 Learning			L3 Behaviour			L4 Result		
	Indicators	Metric	Data	Indicators (Domain: Level)	Metric	Data	Indicators	Metric	Data	Indicators	Metric	Data
Instruction design plan of research. Learner population: educators (lecturers, professors, course coordinators, deans) of public health, life sciences and technology, human or veterinary medicine programs/schools/colleges (HEIs)												
Instruction Design	The participant is satisfied, interested and engaged	≥4,5/5 average evaluation	Post-instruction survey	Knowledge: Understand: what to look at to characterize learners and instructional context	The participant compiles an instructional characterization considering audience and context characteristics	Post-instruction survey; workshop activities; Design Documents	Teaching to students	The participant teaches to students applying what learned in Level 2	HEIs' syllabi; situational analyses; interviews	Formal introduction in instruction programs (new or revised credited instruction)	Education is integrated in an instruction program; formalized, including but not necessarily with credits; does not depend on individual effort; and/or learning objectives are stated in the program design.	Formal introduction in instruction programs (new or revised credited instruction)
		≥90% participants evaluating positively										
		All participants participate (notes from learning activities)	Posters from learning activities	Knowledge: Know: components of the training design cycle	The participant lists components of the ADDIE cycle in correct order and describes it as a cycle							
		Appreciations, and/or asking for additional trainings	Follow-up communications; letters; post-instruction survey	Knowledge: Apply: draft learning objectives	The participant designs learning objectives including: differences between cognitive domains and levels of learning; only one objective per statement; consistent with the learner characterization; evaluable	Design Documents						
		% attendance	Turnout at the event; attendance sheets	Knowledge: Apply: design instruction	The participant compiles a Design Document that includes identification of desired impact in terms of deliberate disease risks; identification of the instructional problem; learner characterization; learning objectives; evaluation strategy; course description; instructional environment; outline							
		The participant asks questions	Active participation during training; forums; observation	Knowledge: Understand: different learner-centred delivery techniques	The participant gives examples of learner-centred instruction techniques, such as principles; adaptation to sensory styles; Kolb's cycle, etc.	Post-instruction survey; workshop activities; instructional materials develope						

						d by participants						
				Skill: Apply/Analyse: use learner-centred education development and implementation methods	The participant develops a lesson plan, a learning activity or a guided exercise for students using learner-centred teaching techniques	Instructional materials developed by participants; peer review "rubrics" by participants						
					The participant delivers a lesson plan, a learning activity or a guided exercise for students using learner-centred teaching techniques	Instructional materials developed by participants; Peer review "rubrics" by participants						
				Knowledge: Evaluate: evaluate education	The participant designs evaluation for their education including indicators, metrics and data for the four Levels	Design Documents						

6.5 Conclusions

This Chapter discussed the Design phase of the ADDIE ISD model applied to education on deliberate disease risks, within biorisks, for higher education. The first aspect introduced has been the definition of learning objectives. After reporting on preliminary identification of objectives, I have discussed guidelines from instructional design on defining learning objectives, as well as different examples of their characterization. I have detailed the taxonomy of learning objectives based on cognitive domain and level of learning, developed on the bases of science of learning introduced in Chapter 2. Specific designed learning objectives from the projects considered in the research have then been presented. Regarding the education plan of research, I have noted how learning objectives in higher education should include foundational aspects of biorisk management as well as advance capacities on the risk-based approach; and that learning objectives in pre-service are more generic (lower cognitive domains and/or applicable to a wider range of cases) than for in-service learners. Furthermore, I illustrated how learning objectives are matched to information collected in Analysis and introduced the design document tool, used both as a design instrument in the education plan and as an instructional instrument to train educators on instructional design in the instruction plan. I presented examples of designed education with and by educators in projects considered in the research.[395]

The last part of the Chapter designed proposed strategies for evaluation of education to mitigate deliberate disease risks in the education and instruction plans of the research. Regarding the former, drawing from the experiences presented earlier, I designed learning objectives as Level two indicators in four thematic areas. I also designed corresponding indicators for Level three and Level four evaluation. I argued that capacities built through these objectives have the potential to influence likelihood and/or consequence of deliberate disease risks in the three risk scenarios described in Chapter 3. In particular, the (bio)risk management thematic area would have the potential to influence

[395] Designed educational programmes included a “problem/rational/aim/overview” statement; target learner description, including their prerequisites; the anticipated next steps for the learner; defined and categorized learning objectives; evaluation strategies for the four Levels; and information such as duration of instruction, prerequisites of the instructor(s), number of students, planned delivery techniques, and references to educational resources.

risk in all three reference scenarios. The laboratory biosafety thematic area would have a less direct influence on deliberate disease risks but it would still have the potential to influence (though indirectly) risk in the second scenario. The laboratory biosecurity thematic area would have the potential to influence risk in the second (outsider threat and/or misuse) and third (insider threat) deliberate disease risk scenarios. The broader biosecurity and dual-use management thematic area would have the potential to influence deliberate disease risks under the three scenarios.

Regarding the instruction design plan, similarly, indicators are designed that, in Level two, are learning objectives for educators as they learn to apply the learning-by-design and learner-centred pillars on education on biorisks, including deliberate disease risks management. Behaviour and Result indicators are also designed, in the fourth Level looking at formalization of education in the higher education context. In both plans, indicators in the four Levels are accompanied with possible metrics and data sources that complete the evaluation tools. These evaluation tools will be applied to data from the projects considered in this research in the Evaluation Chapters, where several among these indicators and metrics will be used. Before moving to that, however, we need to discuss the Development and Implementation phases of the ADDIE model of ISD applied to education on deliberate disease risks in higher education.

7. Development and Implementation

This Chapter discusses the Development and Implementation phases within the ADDIE model of ISD for education to mitigate deliberate disease risks. Development and Implementation are discussed together firstly because they are strictly linked and secondly because Implementation is really the practical realization of everything planned during Development. Hence we don't need here to devote specific and separate spaces for Development and Implementation, with the observation that what was described in this Chapter has actually been developed and implemented in real courses, or is based on the experience of actually implemented courses.

The Development phase in ISD focuses on producing the lessons plans and the materials and tools[396] to use in education for the student to reach the designed learning objectives, while the Implementation phase focuses on delivering those materials to students. The complex of products is referred to in different ways in the ISD literature; Hodell (2011 p. 60) uses "lessons plans", while others refer to them as course plans or teaching guides. In our interaction with HEIs, it emerged that HEIs often have their own nomenclature for lessons plans.[397] One useful step to move from Design to developed lessons plans, is drafting the key message(s) that the educational content will deliver (Grainger and Turegeldiyeva, 2015). Subsequently, instruction designers should consult and review the educational resources that had been mapped in the design document to match learning objectives and key messages. Education should build on learner-centred instruction (Jensen, 2005; National Research Council, 2000). This impacts not only the content but also the order and the delivery methods of education.

In the following paragraphs, models and insights from educational science that have been mentioned in Chapter 2 will be leveraged for the Development and Implementation of education based on Design, primarily including the nine events of instruction (Gagné et al., 1992), principles and elements of learning

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[396] Including educational materials but also teaching support and other materials for instructors, such as presentations, notes, handouts, scenarios, case studies, reading lists, videos, exercises, tests, questions, exams, teaching guides, etc.

[397] In the considered projects, the complex of teaching tools was referred to as "syllabus" (note that in some cases "syllabus" rather denotes the design document of a curriculum and not its lessons plan), "lectures package", "course work", or "document set".

(Thorndike, 1932; Halpern and Hakel, 2003), the Jensen's model for learner-centred instruction (Jensen, 2005), and the Kolb's cycle (Kolb, 1971; Kolb, 1984; Kolb et al., 2001; Kolb and Kolb, 2005). It will also become apparent how often these models are connected and how instructional Development and Implementation can, in practice, follow their suggestions for effectively achieving learning objectives.

7.1 Develop agendas for instruction

Deciding the order in which instruction is imparted is not a trivial issue as it may have significant influence on if and how learning objectives are achieved by students (Schmidt and Bjork, 1992). The primary source for organization of agendas of instruction is the model of nine events of instruction as described by (Gagné et al., 1992),[398] based on instructional psychology studies (Gagné and Rohwer, 1969).[399] Most of the findings for the events of instruction model came from studies with young students, however subsequent applications with adult learners indicate they are successful with them as well (Bonner 1982). This is a particularly important finding for higher education, as lectures are the dominant delivery method in teaching life sciences in HEIs, mostly because it is perceived as cost effective method, and easier to control coverage of content (Goffe and Kauper, 2014).

The nine events of instruction as proposed by Gagné and Briggs include:

1. Gaining attention
2. Informing learners of the learning objectives
3. Recall of previously learned content
4. Presentation of new material
5. Guidance of learning
6. Eliciting performance
7. Providing feedback
8. Assessing the performance
9. Aid future retrieval and transfer

[398] Learners are more likely to retain concepts and skills if these are presented in ways that support how the mind works (Gagné et al., 1992).

[399] This model is also compatible with other inputs I leverage from educational science, such as Jensen's (2005), which suggests what instructional actions should be planned before, during and after delivering to students.

Hodell (2011) has proposed both a rebranding and a simplified and more practical repackaging of the nine events into three phases: Preparation for learning (including Gaining Attention, Direction and Recall); Delivery and practice of new material (including Content and three phases of feedback from students); and Wrap-up (including Evaluation and Closure). I use this simplified grouping in the discussion below.[400]

7.1.1 Preparation for learning

Preparation for learning should start with gaining the attention of the student; this is an event too often overlooked in traditional higher education settings. One way to do that in a university course may be to carefully choose a pre-course reading assignment that is simple and engaging, such as a story in the news that is relevant to the topic, or starting the course with telling an experience from real life. The Direction event includes informing the students of the designed course's objectives. Bonner (1982) suggests that for adult learners, educators should "choose the learning objectives" with the learners, rather than present them as pre-determined. However, as we discussed, objectives should at this point at least have been drafted, if Analysis and Design have been duly carried out.[401] Even if learning objectives should or could not be changed, they should still be discussed with students at the beginning of instruction to check they are understood, and any additional expectations should be collected. The Recall event implies connecting with known or prerequisite information (Knox, 1977); it also helps checking that students actually have all prerequisites assumed during Design.

7.1.2 Delivery and practice of new material

The following section of the repackaged nine events focuses on the delivery and practice of new educational material. The stimulus material should be presented with the features of learner-centred instruction in mind. They should be organized with increasingly autonomous activities assigned to students, use animation and face-to-face work rather than read lecturing (Gagné and Rohwer, 1969), as well as take into account the Kolb's cycle, moving from practice to abstraction to reapplication. Under "Content" ("Presentation of new material" in

[400] However, it is still important that the nine events occur in the proposed order to assure information is presented in the way the learner processes it.

[401] Furthermore in the higher education context, learning objectives are usually formally defined before any interaction with students.

the original events), the student is presented with new stimulus material organized in a meaningful way. Suggestions for this organization include introducing “spikes” in difficulty (i.e. levels of learning) that have the potential to enhance retention (Ghodsian et al., 1997), while not discouraging students as it would keep a manageable level of “memory load”[402] (Nesbit and Hunka, 1987). Subsequently, an instruction developer should plan to aid students in learning contents and resources;[403] help students internalize new skills and knowledge;[404] and to provide immediate feedback to students.[405]

7.1.3 Wrap-up

The final step of wrap-up would include Evaluation and Closure, which not only should provide for methods to evaluate the achievement of learning objectives, but also include key steps to enhance retention, further application and guidance of the students on the relevance of what they learned. Regarding both Evaluation and retention, it should be noted that besides being considered at the end of the lessons plan, space should be provided also at points during the previous phases, so that Evaluation is continuous and builds up during the curriculum, and grasp of key messages is facilitated when they are presented. For higher education students, guidance by the facilitator during closure on where and how the completed curriculum relates with the larger course of study is fundamental for students to understand the integration of deliberate disease risks management with their technical formation.

7.2 Delivery techniques that enhance retention

As discussed in Chapters 2 and 6, learner-centred instruction (or “active learning”) has increasingly been suggested as more effective than instructor-centred lecturing (Colliver, 2000; National Research Council, 2000; Prince, 2004; Armbruster et al., 2009; Haak et al., 2011; Ruiz-Primo et al., 2011; S. Freeman et al., 2014). However, I have also noted how the science of learning, including learner-centred modes of delivery, is not traditionally applied in higher

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[402] Or the “relative estimate of the inhibition effects contributing to the forgetting of prerequisites in a sequence with an underlying hierarchical structure” (Nesbit and Hunka, 1987 p. 142)

[403] “Guidance of learning” in Gagné et al. (1992) , “Application feedback Level 1” in Hodell (2011)

[404] “Eliciting Performance” in Gagné et al. (1992), “Application feedback Level 2” in Hodell (2011)

[405] “Providing feedback” in Gagné et al. (1992), “Application feedback Level 3” in Hodell (2011). It should be noted how the nine events of instruction, including in Hodell’s (2011) “repackaging and rebranding”, are also reflected in, and compatible with, Kolb’s suggestions on experiential learning and the cycle between abstraction and application.

education in many countries (Halpern and Hakel, 2003). What presented in Chapter 5 on Analysis seemed to confirm this indication, adding that sometimes lecturing may be necessary due to instructional context constraints such as the size of students' cohorts or the availability of teaching aids and materials. In fact, lecturing would not always, or not completely, be a wrong instructional choice. Lectures could be acceptable, for example, for lower levels of learning and/or theoretical knowledge cognitive domains.[406] Nonetheless, effective education to mitigate the risks of deliberate disease should try to apply learner-centred methods in Development and Implementation according to the possibilities outlined in Analysis and Design. Below are some guidelines and practical examples of application that have been drawn from the experience of developing and implementing education on biorisks, including deliberate disease risks, management.

7.2.1 Applying principles of learning

Principles, or elements, of learning, were proposed (Thorndike, 1932) as practical suggestions on developing instruction materials in ways that would enhance retention. They would include readiness, recency, exercise, intensity, effect, freedom, primacy and requirement.[407] These principles are reprised by more recent pedagogy literature under different labels (Halpern and Hakel, 2003), as well as compatible and overlapping with Gagné's events of instruction[408]. Principles of learning can indeed be linked to specific events of

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[406] Lectures would be "a satisfactory arrangement for learning if the desired outcome is to produce learners who can repeat or recognize the information presented. But is one of the worst arrangements for promoting in-depth understanding" (Halpern and Hakel, 2003 p. 40).

[407] Readiness implies that instruction should be appropriate for the student's previous capacities, prerequisites and expectations (they should be "ready" to learn), and as such is highly dependent on Analysis; recency suggests that recent information are more easily remembered; exercise implies the reiterated or repetition of information; intensity the use of colours, graphics, audio, highlighting, dramatization; effect suggests inserting change, surprise and the breaking of routine in instruction; freedom the possibility for the student to achieve learning objectives, and/or to follow instruction, with different options (for example by choosing exercises, essay questions, or taking a course at their own time); primacy suggests leveraging first impressions, and placing important content at the beginning of instruction; and requirement the importance of connecting new content to existing one, provide a starting point and explain the context of new topics.

[408] Gagné et al. (1992) suggest (a) techniques to gain and maintain the attention of the learner; (b) establish within the learner certain preconditions for learning by giving pretraining, by providing verbal directions, by stimulating recall; (c) present the stimuli directly involved in learning as actual objects and events, printed materials, or pictures, among other forms; (d) aid the learning process by methods of prompting and guiding, often in the form of verbal communications; (e) specify the conditions for

instruction, and practical examples of applications during Development and Implementation of education on biorisks, including deliberate disease risks, management, can be mentioned.

The requirement principle, for example, pairs with the third event "Recall of prerequisite information". Ways in which the instructor can apply the principle include asking students to think of experiences or cases they lived or know about that would be relevant for the learning objective. During the first event, "Gaining attention", the instructor can plan to use the intensity and/or the effect principles surprising students with an unusual request, a new activity, new class set-ups, or though-provoking questions. During the second event, "Stating objectives" ("Direction" under Hodell's version), the freedom and readiness principles can be applied by establishing with the learners criteria for instruction and performance, or developing together rubrics or scorecards for risk assessments. During the fourth ("Presentation of new material", or "Content" in Hodell's version) and fifth ("Guided learning") events, several principles of learning should be used as guidelines for developing and implementing education, by including real-world examples and multimedia, or using pictorial elements that are more effective than verbal ones, and concrete verbal elements that are superior to abstract verbal ones (Gagné and Rohwer, 1969). Exercise can be applied within the fifth event "Guided learning" as well as the ninth one "Retention and transfer".[409] Practical ideas to practice the exercise principle in these phases would include asking the student to teach to other students, or compile a list of "frequently asked questions" to be answered by students in class or online, individually or as a group.[410] During the sixth to eighth events ("Elicit performance", "Feedback" and "Assessment"), ideas for Development and Implementation include application activities by students, elaboration, occasions to collect confirmatory or corrective feedback, questions post-presentation of new material. Techniques for Development and

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responding as in the contract between overt and covert responses; (f) employ methods to provide feedback to the learner concerning the correctness or incorrectness of his performance at various stages of learning; (g) establish conditions to promote retention, including such factors as repetition and rehearsal; and (h) use techniques which enhance the transfer of learning to subsequent learning tasks or other performances.

[409] As Halpern & Haken (2003 p. 39) note, the "benefits of retrieving information learned earlier to produce answers in response to new questions are among the most robust findings in learning literature".

[410] This also provides opportunities to practice the "freedom" principle of learning.

Implementation of learner-centred education in the "Retention and transfer" (Hodell's "Closure") ninth event of instruction should apply principles in looking at reapplication of learning outside and beyond the limited space and time of training, for example by having students develop specific security job-aids for their daily activities, drawing concept maps, or reapplying risk assessment methods in a real-world scenario.[411]

Regarding instruction delivery techniques for desired skills, simulations, games and role-playing have the potential to enhance learning (Level two evaluation) and transfer to behaviour (Level three evaluation) with respect to lecturing (Gopher et al., 1994; Goettl et al., 1996; Jentsch and Bowers, 1998). Games (Ricci et al., 1996) and simulations (Kaufman et al., 2007) have also been applied and proved successful in training for in-service personnel[412] on managing safety and security risks in the chemical and biological sciences.[413]

7.2.2 Addressing different types of students

Learners have different learning styles (Tanner and Allen, 2004), which means they will learn (i.e. achieve Level two in Evaluation) and retain/transfer (i.e. achieve Level three in Evaluation) to different extents depending on ways in which instruction is presented to them (Halpern and Hakel, 2003), primarily during the fourth and fifth events of instruction. For example, Rosati et al. (1988) describe students along an intuitive-sensing scale. Intuitive students would have a preference for "abstract, global and theoretical" approaches, while sensing students for "practical, factual and specific" information.[414] Gardner's (2011) "multiple intelligence theory" distinguished students based on their preference to absorb information, using categories such as linguistic-verbal, logical-mathematical, visual-spatial, bodily-kinaesthetic, musical-rhythmic,

[411] Note how these examples of techniques applying learning principles in the last event of instruction are very much in line with the third level of evaluation ("Behaviour", also called "transfer" in literature) in the four-level model of evaluation of education that I also employ in this research.

[412] In the latter example, students were asked to construct a laboratory and place equipment in the appropriate areas; develop a communication message for an incident; conduct risk assessments; and package samples for shipment (Kaufman and Berkelman, 2007).

[413] A type of simulations, role-playing is based on "behavioural modelling" or "reproduction" by learners, and has the potential to increase generalization of desired behaviour time after education is imparted.

[414] Rosati et al. (1988 p. 209) evaluated achievements of learning objectives by students characterized by different preferences and presented with instructions with two different approaches, one with "emphasis on derivations, concepts, and theoretical treatments with extrapolations; the other with emphasis on details and numerical rather than algebraic in-class examples".

interpersonal, intrapersonal, and naturalistic. Similarly, Felder and Silverman (1988) identified different "dimensions of learning" in the sciences, such as sensory-intuitive, visual-verbal, active-reflective, and sequential-global. Without discussing in detail these categorizations, or their cognitive and psychological basis, it seems reasonable to accept that learners may have different preferences impacting the achievement of Level two and Level three indicators for education Evaluation. This would be particularly relevant when education for groups of students has to be developed and implemented. It is desirable hence that instructors plan a variety of concrete, abstract, pictorial, active and reflective elements in their lessons plans to reach and help different types of students. Kolb (Kolb, 1971; Kolb and Kolb, 2005) also advanced the idea of different learning styles, which should be considered in combination with the Kolb's cycle. He posits that affections and experiences would influence learners in being more or less extravert or introvert, sensing/feeling or thinking. Kolb suggests that these differences would influence where in the cycle of experiential learning a student would prefer to start to learn new material.[415]

7.3 Development in the education plan

In developing education to achieve learning objectives of deliberate disease risks mitigation, the above considerations on agendas of instruction and delivery techniques have been applied as much as possible. At the same time, these experiences, including challenges, were useful to inform the general guidelines and examples organized in the previous paragraphs of this Chapter. The most pressing requirement for Development and Implementation of education on deliberate disease risks, however, remains that of the learning-by-design pillar: instruction has always to be based on Design and activities have to be consistent with the level and cognitive domain of the set learning objective(s).

[415] Kolb groups learning styles in Diverging, Assimilating, Converging, and Accommodating. In the cycle, Kolb identifies two "dialectically related models of grasping experience: Concrete experience (CE) and Abstract Conceptualization (AC) – and two dialectically related modes of transforming experience – Reflective Observation (RO) and Active Experimentation (AE)" (Kolb et al, 1999, p 3). Different learning styles would hence not change the experiential learning cycle model, but influence from what experience different students would prefer to start – some students may prefer to start from the Abstract Conceptualization, while others from Active Experimentation. In this sense, Kolb's structure can be read as a complex of a model for the learning process, a categorization of learning styles, and a guidance for developers and implementers of education to organize content in agendas of instruction.

7.3.1 Customize existing educational resources

One of the options when developing education is to use existing educational material resources, such as the Sandia National Laboratories' GBRMC (Sandia National Laboratories, 2013), the ERM by the Bradford Disarmament Research Centre, the National Defence Medical College and the Landau Network-Centro Volta (Whitby and Dando, 2010a), or the University of Bradford's Guide and Handbook of Biosecurity (Whitby et al., 2015; Novossiolova, 2016), and configuring or customizing them according to Design. In the experiences considered in the research, a similar option has been pursued for example for the development of the course work for the credited course in Country A University 1; and during the EUBARNet seminars for students, courses from the ERM were leveraged to customize contents according to guidelines discussed with local professors.

7.3.1.1 Team-based learning format

One practical example comes from the seminar format on dual-use issues related to biosecurity designed within the EUBARNet and Project 18 projects. The seminar format implemented a Team-Based Learning (TBL) approach to teach dual-use issues to life sciences students.[416] TBL is a special form of collaborative active learning[417] that uses a specific sequence of individual work, group work and immediate feedback to create a motivational framework. TBL has been tested in different forms and evaluated with positive results (Bowers et al., 1993; Cannon-Bowers and Salas, 1998). The TBL structure used in these seminars included a pre-instruction reading activity, an evaluation questionnaire, an Individual Readiness Assurance Test (iRAT); a Team Readiness Assurance Test (tRAT), a Feedback Session, one or more Team-Based Application Exercise(s), and a final evaluation questionnaire (Novossiolova et al., 2013).

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[416] The format has been used for the UK seminar within the EUBARNet series (the approach had been used by the same university to teach the entire undergraduate programs in the school of Pharmacy). Similar applications of the TBL format were carried out with higher education students in three Project 18 seminars, as well as with professionals in another Project 18 seminars and with either students or professionals in four more TBL seminars in various countries. Experiences and formatted materials for instructors were organized in the Handbook for Biosecurity (Novossiolova, 2016), which confirms how the TBL format can be applied to different areas of biorisk management instruction, including deliberate disease risks management.

[417] Collaborative learning denotes "situations where trainees are trained in groups, but not necessarily to perform a team task" (Salas and Cannon-Bowers, 2001 p. 482).

In an example of a seminar from Project 18 developed with the TBL format, the phase of “Preparation for learning” included stating and explaining the learning objectives[418] to students and conducting Readiness Assurance Tests on the assigned reading materials, both individually and in small groups. The phase of delivery and practice of new material included a first exercise on a scenario based on the H5N1 gain-of-function research, which asked students to discuss and explain options on regulating the research and/or its publication; a second exercise in which each small group was asked to develop a poster to raise awareness and explain to other students the issues of dual-use in biosecurity; and a third exercise on a scenario based on the Mousepox IL-4 experiment. The Wrap-Up phase included an evaluation with feedback from students on what they liked, what they learned, their opinions on dual-use and how they could apply what learned in their practice.

7.3.2 Develop new instructional material

In other cases, when it was not possible or appropriate, based on insights from Analysis and Design, to customize existing educational resources for some learning objectives, work has been done to create new instructional materials. This was often realized in connection with the ISD workshops with local higher education teachers; and products often took the form of learning activities for students focused on specific learning objectives. Development of this material served two goals: on the education plan of the research to Develop appropriate instruction materials for the end students; and on the instruction design plan of the research to have ISD workshops’ participants exercising in applying the learning-by-design and the learner-centred[419] pillars for instruction Development and Implementation.

For example, in the Country B project, the doubts of HEIs professors on the suitability of existing instructional material as direct resources for education emerged during the first ISD workshop focusing on Analysis and Design, and led to proposing the Development of specifically-designed learning activities for students that would complement available materials. The project team mentored participating professors on developing learning activities, each

[418] That included “know what dual-use, misuse and security issues are; be able to communicate dual-use issues; discuss and defend positions on dual-use governance”.

[419] Including effective agendas for instruction; effective delivery techniques; and consideration of different learning styles.

focused on a single learning objective derived from the design documents they had previously drafted and deliverable in a 30 minutes to one-hour lesson.[420] Professors were requested to include at least one learner-centred component in the activity, which could be complemented with lecturing and assignments for students. This proved useful for the professors to practice in developing course work following Design; and for me and other facilitators to test mentoring in developing guided exercises, which is relevant for the instruction design plan of this research. Each participant was asked to develop both the lessons plans of the learning activity and the specific instructional materials to Implement it. The ideal document set included a compiled form serving as “Develop Document” and a guide for instructors; a slide deck for a presentation; supplemental material like scenarios and reading lists for students; Evaluation tools such as feedback questionnaires, test questions and behavioural indicators to evaluate both Level two and Level three impact of education. Obviously not all guided exercises resulted in such an ideal product, but several were more than satisfactory.[421]

Different examples of Development of new instructional materials come from the experience with the ISIS Master in Biotechnology and Neurosciences. This included using distance-learning options to deliver education on deliberate disease risks, as the module on “Dual Use and Militarization of Neuroscience” within the course on “Bioethics, Regulations and Laws”, was largely imparted at distance. Nonetheless, we applied principles of the learning-by-design and learner-centred pillars to the Development and Implementation of distance-learning education on deliberate disease risks.[422] The lessons plan included two sessions on Skype between students and instructors, that were anticipated by an invitation with background information and pre-reading via email and roughly followed Hodell’s sections for instructional agendas discussed above. They also interposed lecturing with dedicated questions & answers moments when students could submit in writing in real time. Later students had the opportunity

[420] This requirement was rather arbitrary and decided as something that was feasible to present at the second ISD workshop focusing on Development, Implementation and Evaluation. It then became clear that the standard “lesson module” format in Country B is 50 minutes long.

[421] During the drafting period leading to the second ISD workshop focused on Development, Professors were also asked to Implement (“test”) their guided exercise with their students, if possible.

[422] I prepared Design and Development, and Implementation was carried out by me and two colleagues from the Bradford Disarmament Research Centre.

to access the recording of the sessions from the Master's Learning Management System (LMS) platform.[423] Furthermore, it included an online forum on the LMS, where each student was required to post at least one question relevant to the topics of dual-use and security issues in neurosciences discussed in the live sessions, and to respond with their opinions to other students' questions. Finally, students were required to submit a one thousand words essay to solicit the higher level learning objectives. Students could choose between a more practical and experiential theme and another more abstract and reflective.

7.4 Development in the instruction design plan

While for most of this Chapter until now I discussed Development and Implementation in relation to the education plan of the research (i.e. where users of lessons plans and educational materials are students of life and connected sciences and technologies), these phases of the ADDIE instructional design cycle have also been applied to the instruction design plan of the research, where the learner population is made by educators (lecturers, professors) from HEIs. Development and Implementation on this plan follows a simple train-the-trainer[424] concept, implying that educators would first learn about the subject matter of deliberate disease risks management within biorisks management, and then learn how to teach it applying the learning-by-design and the learner-centred pillars in their education of students. Development and Implementation of train-the-trainer lesson plans and instructional materials, as for any instruction and as described under the education plan, has to be based on Analysis and Design; hence for this research it has been geared towards achieving the learning objectives for the instruction design plan, presented in Chapter 6 as Level two (Learning) indicators.[425]

Lessons plans and instructional materials for the instruction design plan strove to strategically apply guidelines such as those on agendas for instruction and

[423] As an effort to apply the "freedom" principle – tough students were strongly invited, by both us "external lecturers" and their own local professors, to attend the live session.

[424] Also known as trainer development and training-of-trainers.

[425] As a reminder, they include: Knowledge: Understand: what to look at to characterize learners and instructional context; Knowledge: Know: components of the training design cycle; Knowledge: Apply: draft learning objectives; Knowledge: Apply: design instruction; Knowledge: Understand: different learner-centred instructional techniques; Skill: Apply/Analyse: use learner-centred education development methods and implementation; and Knowledge: Evaluate: evaluate education.

delivery techniques such as the principles of learning; addressing different learning styles; and the Kolb's cycle of experiential learning. Developed instruction in this plan is also based on the ADDIE cycle and facilitates participants through analysing, designing, developing, implementing and evaluating education for their students on deliberate disease risks. For Analysis, materials such as the questionnaires and ISD workshops' contents presented in Chapter 1[426] have been developed to guide participants on collecting valuable information on their student population and educational context. Some of the instructional activities for Analysis started before the actual meeting with participants, typically through pre-workshop email surveys. These were also occasions to send participants clear information about the objectives of the workshop as well as suggested (or required) reading materials, in line with the Direction event of instruction. Most of the learner-centred train-the-trainer instruction however took place during in-person ISD workshops,[427] where participants are guided through collaborative learning exercises. Activities planned at the beginning of these events included collecting expectations from participants, before presenting again and, if necessary, discuss and revise, the learning objectives. In-person guided exercises for achieving Analysis were developed to review and revise pre-workshop surveys. To introduce participants to Design, facilitated teaching activities have been developed, such as brainstorming over the seemingly simple question of "why do we teach?". In this case participants were encouraged to come up with any meaningful idea, while the designed role of the facilitators was to lead them to realize that the ultimate goal of education on deliberate disease risks is "to reduce deliberate disease risks". This exercise has been quite appreciated in the higher education context to make participants look further than just attaining students' learning, but to keep in mind the more general goal.[428] The concepts and categorizations of learning objectives were subsequently introduced for Design, and participants

[426] Including those that led to results presented in Chapter 5.

[427] As mentioned in Chapter 1, typically agendas for ISD workshops were developed over an intensive five working days schedule to cover the various phases of ADDIE. However, in some cases they were split in two workshops, a first one covering Analysis and Design, and a second one covering Development, Implementation and Evaluation. In these cases, the time between the two workshops was used for mentored Design and Development of lessons plans and materials.

[428] And, even if participants don't know it yet at this point of instruction, prepares them to appreciate Level four in the four levels model of evaluation of education.

guided in exercises in which they identified and assigned appropriate learning objectives to their analysed student population(s). Participants were also presented with the Kirkpatrick's model of four levels of evaluation of education, and facilitated in planning Evaluation methods feasible in their higher education context but appropriate for each learning objective.[429] At this point, the instructional material of the design document template proved helpful for participants to collect and organize information, as described in Chapter 6. Regarding Development, participants were presented with insights from the science of learning, such as the principles of learning, developing agendas for instruction, different learning styles, and the Kolb's cycle.[430] Learning activities and exercises included the facilitated preparation by participants (in groups or individually) of new instructional materials for students, applying the learner-centred educational techniques, as those described in the previous paragraph. Train-the-trainer instruction for participants on the phase of Implementation of deliberate disease risks education was developed including structured occasions for participants (individually or in groups) to teach-back the materials they developed to the rest of the ISD workshop group. Participants were invited to exercise the techniques of the learning-by-design and learner-centred delivery pillars.[431] Finally, and moving to the Evaluation aspect of the ADDIE cycle, participants are guided through not only evaluating the effect of education (via devising Evaluation methods for Levels one to four, connected to the learning objectives they designed for their students), but also on evaluating the use of the training-by-design and learner-centred delivery pillars in instruction.[432] A useful activity in this phase was the creation of rubrics, or scorecards, to peer-review and provide feedback on each-others' products of

[429] This exercise is particularly useful, for example, to highlight how Level two Evaluation cannot limit to pen-and-pencil tests if the learning objective requires a practical skill.

[430] Participants to ISD workshops were not presented with detailed theoretical background on these instructional theories, nor with an extent of references comparable with what discussed earlier in this Chapter. Rather, participants were offered a "toolbox" of learner-centred instructional methods to practice during Development – it should be reiterated that the primary goal of these train-the-trainer programs was in fact to promote education on deliberate disease risks, not learner-centred education per se.

[431] Regarding practicing Implementation it should be noted that the ISD train-the-trainer format often includes occasions for participants to co-train with already developed instructors in subsequent instructional events teaching the subject matter of biorisks management to other groups.

[432] This is useful for them also as self-evaluation, it responds to events of instruction, and is an important capacity for participants, as they become instructional designers.

Development and Implementation.[433] This was useful not only to provide occasions for “Elicit performance” and “Feedback”, but also to practice the principles of exercise as well as freedom (as criteria are not pre-determined by the instructor, but selected by participants).[434] Development of lessons plans and materials for the ISD workshops included planning recaps and reviews at key points, including before moving from content on one ADDIE phase to the other and before and after breaks, in line with the primacy, recency and exercise principles. Materials include colourful pictures, graphical schematizations, as well as activities requiring the participants to move around the class, not only to apply the intensity and effect principles, but also to hopefully keep the attention of participants with different learning styles.

7.5 Implementation

The Implementation phase within the ADDIE cycle can also be described along the two plans of the research, education and instruction design. The goals would be, respectively, implementing education as delivering it to students, and implementing education as formally introducing it in the HEIs’ curricula, connected to Level four and Level three evaluation in the instruction design plan, respectively.

Regarding the former goal, short-term Implementation seems feasible. Professors engaged in education projects should be encouraged to Implement what they have designed and developed in the teaching to their students. Often professors have the autonomy to introduce new modules in the courses they already teach, or to organize extra-curricular activities or seminars. Sometimes they can frame the new education within already existing learning objectives. Educators who participated in ISD workshops and became instructional

[433] Here the instructor facilitated participants in selecting items and criteria for desirable or standard performance that they would seek in well developed and implemented educational materials on deliberate disease risks, and then they used it to peer-review and provide feedback (the instructor/facilitator(s) would make sure that is anonymous and constructive feedback) on teaching materials.

[434] Experiences with ISD workshops suggest that participants indeed select very meaningful criteria for the Evaluation of Development and Implementation products. Examples include: “was the activity memorable?”, “was the activity relevant to the lesson’s objective?”, “did the training address different types of learners?” (from Region A ISD workshop); “is the activity relevant to the learning objective?”, “is the key message states at the beginning […and…] at the end?” (from Country B ISD workshop); “the training contributes to the larger objective for societal benefit (biorisk reduction)”, “the training addresses different types of learning styles”, “the training was relevant to the audience for which it was designed” (from Country C ISD workshop).

designers on deliberate disease risks education, should also be encouraged to test the developed materials as an occasion to review and improve them. It should be noted that, often times, Development and Implementation are carried out by different people: the person who develops lessons plans and instructional materials may not be the same person who delivers it to students.[435] This stresses the importance of sound and comprehensive Development, so that different implementers have the possibility of applying the materials, hopefully having students achieving the same learning objectives. Developers and implementers may also need different capacities, for example the former being stronger in developing agendas for instruction and the latter on learner-centred teaching techniques.

Implementation of developed education materials has been experienced by several Professors engaged from Country B's universities; some of the professors from Region A universities; and professors from the European universities participating in the EUBARNet project. The large majority of Implementation with students was realized in classroom-based teaching environments, even if I have accounts from professors of discussion seminars, laboratory sessions, and field visits implemented according to Development. In some cases, interest for distance-learning Implementation has been raised, including bringing examples of successful experiences with e-learning programs.

Implementation as education delivery to students in existing courses, while achieving the short-term objective of introducing the designed and developed curricula and generating feedback, however, does not guarantee sustainability. Courses could be changed, and new topics could rotate in the "flexible" shares of courses. More importantly, short-term initiatives often depend on the individual educators (or coordinators or deans) and new staff member may not be as aware of the importance or interpret learning objectives the same way. If education on management of biorisk, including deliberate disease risks, is analysed as a necessary component of technical education, it should be explicitly introduced in learning objectives and built into the formal course designs. Implementation on this plan would be assessed in Level three and Level four Evaluation in the instruction design plan of the research, and will be discussed in more detail in the following Chapter.

[435] As for a lecturer who employs teaching material from a professor or a course coordinator.

7.6 Conclusions

The Development phase in the ADDIE model of ISD consists in preparing lessons plans and all instructional material needed to realize the educational programme, based on the Analysis and Design phases. The Implementation phase consists in carrying instruction to students according to Design and using the developed lessons plans and materials. In the instruction design plan of the research, Implementation also refers to educators teaching to their students and education becoming formalized in higher education contexts. I presented in this Chapter guidelines on Development that would help in retaining the learning-by-design and learner-centred delivery pillars from educational science; as well as presenting examples of practical applications of those guidelines taken from, and informed by, the experience from the projects considered in the research in different countries and socio-cultural contexts. I discussed deciding agendas for instruction, leveraging Gagné's nine events of instruction (though regrouped following more recent ISD literature), principles or elements or learning, issues of addressing different types of students (i.e. students with different learning styles and preferences for learning), and the Kolb's cycle, which describes a learning process but also provides further suggestions on agendas and learning styles. Furthermore, I presented results of experiences in developing instructional materials relevant for deliberate disease risks education, including cases of customization of existing educational resources; application of collaborative learning formats; and creation of new educational materials with ISD workshops participants, that is at the same time Development of instruction in the education plan and a way to reach some Level two objectives in the instruction design plan. In the next two Chapters on Evaluation, I will describe data and experiences from the projects considered in this research in relation to the evaluation tools advanced in Chapter 6, to understand how education on deliberate disease risks could be evaluated after instruction has been developed and implemented.

8. Evaluation in the education plan

This Chapter will discuss the application of the evaluation tools for the education plan of research designed in Chapter 6. Data from the projects are used to provide examples on how – at least some of – the indicators and the respective metrics presented in Table 27 have, and could, be measured. This leads me to suggest if and how education, particularly in the higher education context, could influence assessed risks of deliberate disease in the three risk scenarios, by building foundational capacities in Level 2 (Learning) that lead to behavioural transfer (Level 3) and eventually result (Level 4) on risks. The Chapter will firstly address examples of Evaluation of Reaction (Level 1) from students who received education on biorisk management and deliberate disease risks. Subsequently, I will present data to evaluate the proposed learning objectives organized in the four thematic areas of (bio)risk management; laboratory biosafety; laboratory biosecurity; and dual-use and broader biosecurity – that is, Evaluation at Level 2. Examples on Evaluation of Level 3 (Behaviour) and Level 4 (Result) indicators are then presented, and the potential influence of education on the risks of deliberate disease is discussed.

8.1 Level 1 – Reaction

As discussed during Chapter 6 on Design, a positive reaction facilitates achieving the further levels of impact of training. Instructors can evaluate reaction during or after courses, using a range of tools. Indeed HEIs have generally established practices to evaluate students' reaction with, for example, feedback questionnaires; often these are the same for the whole institution, which allows comparing reaction across different courses. However, Evaluation of reaction can also use less structured tools such as direct observation of students by instructors. In Chapter 6, I proposed one indicator for Level 1, i.e. "the student is satisfied, interested and engaged", and metrics to measure it such as the average evaluation and the share of students evaluating the education positively according to satisfaction surveys; participation of students (or groups thereof) in the learning activities; and comments, attendance and questions from students.

Some of the projects included educational actions involving multiple thematic areas, while others focused on specific ones.[436] While it would be interesting to investigate differences in Reaction from students among the different thematic areas, the available data would not allow controlling if differences in reaction would be due to other variables than the subject matter itself (such as teaching techniques). Hence, data is presented on projects focusing on different thematic areas combined.

8.2.1 Results from post-instruction surveys on students

Examples for measurement of satisfaction from post-instruction surveys come from students from the Pakistan, Country C, EUBARNet and Project 18 projects. These satisfaction surveys used a common approach asking students, anonymously, opinions using Likert-scale questions. While asked items were similar, post-instruction satisfaction survey questionnaires derived from two main models as described in Chapter 1.[437]

As presented in Chapter 6 on Design, the satisfaction indicator from Likert-scale questions in surveys could be measured with the average score from the group of respondents to an item, with the spread of support to an item among the group, or with both. In some way, the former metric looks at the level of interest raised in students, while the latter is more concerned that interest is spread in the class and all students are engaged. Table 29 reports results of satisfaction surveys from students in the Pakistan, EUBARNet, Project 18 and Country C projects. Their feedback has been generally positive or very positive. Over 90% of students in the Pakistan and EUBARNet courses qualified the seminar as at least "interesting", and all students from the Country C course were at least satisfied.[438] Feedback on other questions was also positive, such as that "the

[436] In particular, the courses at Country A University 1 and Country C did not cover the dual-use and broader biosecurity thematic area; the seminar with students in the Pakistan project covered only the dual-use and broader biosecurity thematic area; and most seminars from Project 18 did not cover the laboratory biosafety thematic area.

[437] The Pakistan, EUBARNet and Project 18 questionnaires integrated questions on Level 1 and Level 2 Evaluation. Project 18 questionnaire included a project-specific section and a standardized section developed by UNICRI that focused on Level 1 and also aligned to what piloted in 2008-2009 (Mancini and Revill, 2009). In the seminar at the University of Bradford a local version of post-instruction survey questionnaire had to be employed, which was customized limitedly to some items to evaluate Level 2.

[438] Hence the "interest" item also received the highest score with 4.8 out of 5.

overall quality was high", and "the workshop lived up to my expectation".[439] Further questions asked more specific aspects of satisfaction, a useful feedback for instructors on the appropriateness of Design and Development. Large majorities of students think that the course was articulated in a coherent framework, that their previous knowledge was sufficient to follow the course, that it was relevant to their job or position, and that it touched on contemporary themes related to research. The last three items especially not only confirm students' interest but also suggest the relevance of education on deliberate disease risks management designed and developed along the pillars discussed in the previous Chapters, and more specifically that the courses attended by these students were, generally, well designed based on Analysis.[440] Reinforcing the relevance of education are the answers to the questions regarding previous knowledge and other educational opportunities on the subject. Respondents generally did not think that education on deliberate disease risks was already sufficiently covered in other courses; majorities of students from all projects thought that the subject was not covered in other courses, even if most students also mentioned they had some prior knowledge regarding the potential "hostile use" of life sciences. Finally, large majorities of those students who where presented with the question would recommend courses like the one they attended to others.[441]

[439] We have discussed under Development how it is important to clarify and manage expectations and objectives from the students.

[440] Furthermore it should be noted how students from the Country C course also strongly supported the item "the instructor or teacher was aware/familiar with the topic they discussed and its relevance to my country", suggesting appropriate instructional design not just in educational terms but also for the relevance in the scientific, social and cultural context.

[441] Additionally, 86% of the EUBARNet courses' students also agreed that the same type of seminar could be recommended to improve education on biosecurity issues.

Table 29 - Level 1 evaluation results from post-instruction satisfaction surveys

	Pakistan	EUBARNet	Project 18	Country C[442]	
The topics of the seminar are interesting					Avg
Very Interesting	39% (7)	31% (56)	-	69% (9)[443]	4,8
Quite Interesting	56% (10)	58% (105)	-	31% (4)	
Not so much	0% (0)	9% (16)	-	0% (0)	
Not at all	0% (0)	1% (1)	-	0% (0)	
Unanswered	6% (1)	1% (2)	-	0% (0)	
The overall quality of the seminar was high					
Strongly agree	-	-	42% (189)	54% (7)[444]	4,6
Agree	-	-	47% (212)	46% (6)	
Neither agree or disagree	-	-	5% (22)	0% (0)	
Disagree	-	-	1% (3)	0% (0)	
Strongly disagree	-	-	0% (1)	0% (0)	
Unanswered	-	-	6% (26)	0% (0)	
The seminar lived up to my expectations					
Strongly agree	-	-	32% (145)	54% (7)	4,5
Agree	-	-	52% (235)	46% (6)	
Neither agree or disagree	-	-	7% (33)	0% (0)	
Disagree	-	-	2% (7)	0% (0)	
Strongly disagree	-	-	0% (1)	0% (0)	
Unanswered	-	-	7% (32)	0% (0)	
Are contents of the seminar articulated in a coherent framework?					
Yes/strongly agree	78% (14)	-	42% (188)[445]	69% (9)[446]	4,7
Contents are not very connected with each other/agree	17% (3)	-	46% (208)[447]	31% (4)	
No, teachers can't show clearly the connections	6% (1)	-	3% (13)[448]	0% (0)[449]	
-	-	-	1% (3)[450]	0% (0)[451]	
-	-	-	0% (1)[452]	0% (0)[453]	
Unanswered	0% (0)	-	6% (26)	0% (0)	
Was your previous knowledge sufficient to follow the seminar?					
Yes	44% (8)	28% (51)	40% (182)	-	
Yes, even if having further information would have been helpful	50% (9)	31% (55)	33% (150)	-	
No, but I could follow the seminar easily anyway	6% (1)	37% (67)	16% (74)	-	
No, and this proved difficult	0% (0)	2% (4)	5% (22)	-	

[442] Where 1 is "strongly disagree" and 5 is "strongly agree".

[443] "Strongly agree" to the item "I am satisfied with the training event". Not all students attended all sessions or were present for the survey completion session, so respondents in tables and questions may be less than the total class number (min 12; max 15 students).

[444] To the item "the quality and content of the training materials and presentations met my expectations"

[445] "Strongly agree" to "the workshop presented information clearly".

[446] To the item "The ability, clarity and completeness of the trainer were adequate when responding to trainee questions".

[447] "Agree" to "the workshop presented information clearly".

[448] "Neither agree or disagree" to "the workshop presented information clearly".

[449] "Neither agree or disagree".

[450] "Disagree" to "the workshop presented information clearly".

[451] "Disagree".

[452] "Strongly disagree" to "the workshop presented information clearly".

[453] "Strongly disagree".

Unanswered	0% (0)	2% (3)	6% (25)	-	
The seminar is relevant to my job					
Strongly agree	-	-	32% (146)	77% (10)[454]	
Agree	-	-	41% (186)	23% (3)	
Neither agree or disagree	-	-	10% (45)	0% (0)	
Disagree	-	-	7% (33)	0% (0)	4,8
Strongly disagree	-	-	2% (8)	0% (0)	
Unanswered	-	-	8% (35)	0% (0)	
Did the seminar touch upon contemporary themes related to research?					
Yes and I found it interesting	78% (14)	72% (129)	-	-	-
No, but this is due to the type of the seminar	0% (0)	9% (16)	-	-	-
Yes, but too much	17% (3)	3% (6)	-	-	-
No, this is an important aspect not addressed in the seminar	0% (0)	4% (7)	-	-	-
Unanswered	6% (1)	3% (6)	-	-	-
Were the topics addressed discussed in other courses?					
No	11% (2)	61% (110)	24% (109)	-	-
Yes, but useful to deepen understanding	39% (7)	16% (28)	36% (164)	-	-
Yes, a few	50% (9)	20% (36)	27% (121)	-	-
Yes and too many	0% (0)	0% (0)	7% (33)	-	-
Unanswered	0% (0)	3% (6)	6% (25)	-	-
Had you any prior knowledge about the potential "hostile use" of life sciences?					
Yes	94% (17)	70% (126)	60% (274)	-	-
No	6% (1)	27% (49)[455]	32% (144)	-	-
Unanswered	0% (0)	3% (15)	8% (35)	-	-
Would you recommend seminars like today's to other students?					
Yes	89% (16)	91% (164)	-	-	-
No	0% (0)	4% (8)	-	-	-
Unanswered	11% (2)	4% (8)	-	-	-

Post-instruction surveys can also provide more detailed comments that may help in qualitatively measuring the satisfaction indicator, looking this time at the metrics of appreciation, suggestions or desire for additional training. Comments in open questions from students generally confirm the positive feedback on both the subject matter and the educational approaches. Suggestions for improvement from the EUBARNet post-instruction questionnaires open questions included for example the suggestions for more interaction and more practical case studies, while open feedback questions from Country C students' post-instruction questionnaires included for example:

> *"It was a very interactive workshop, learning was made easier & enjoyable" [C.01]*

> *"Training methods was new for me and I enjoyed it a lot" [C.06]*

Positive feedback in post-instruction satisfaction surveys is also reported by interviewed professors who continued implementation of education on

[454] To the item "The information I learned within the course was important and relevant to my current position".

[455] Includes 5 "not much" answer from the Turin seminar questionnaire version, re-coded as "no".

biorisks/deliberate disease risks after our direct interventions (see also the paragraph on Level 3 and Level 4 in the next Chapter on Evaluation on the instruction design plan), as for example Professor 3 (regarding a course on dual-use and broader biosecurity) and Professor 7 (on a course on laboratory biosafety and biosecurity) mention:

> *Professor 3: "[…] in our country there is a system of teacher evaluation by students. Then we do some sort of sample evaluation for the whole university, and we ask them, which course you liked the most? […] and, can you believe, this was the one that take majority of them, whoever came to this course, and 'this was interesting'".*

> *Professor 7: "[…] I, I to be honest I didn't make it in the form of a survey. Because it's so long, but what I have been…*
>
> *GMM: your impression…*
>
> *Professor 7: not my impression, feedback actually. Came to… from the head of department. That, er, the student is very happy".*

And while survey satisfaction tools are common in HEIs, direct post-instruction feedback from students can also be elicited with questions, as Professor 8 reports:

> *Professor 8: "they liked the topic. Because… er… okay, as a coordinator in this, in biorisk management, I tried to… er… to ask to facilitators… okay, no… ask the students about how they liked when they take… took them through the topics… they said 'yeah, it was very good'.*
>
> *GMM: so you asked them, explicitly*
>
> *Professor 8: I asked them. Because I had… […] sometime after they were going through, going through the exams, I said 'but how did you like the work, whatever', they said 'that was good. It was good, it was interesting'…"*

8.2.2 Results from other evaluation tools

Level 1 Evaluation could also rely on less structured and formal metrics, including but not limited to the observation by an instructor. An example is from group exercises in facilitated learning activities on biosafety and biosecurity, where an instructor uses coloured notes to collect ideas and answers from groups of students. Instructors would assign different colours of notes to the different groups in the class. This allows having an idea of how groups are participating just looking at the different activities' flipcharts.[456]

On the other hand, interviewees suggested that a good metric might also be the requests from students for formal education on the subject, as Professor 2 reports regarding a Master in biosafety and biosecurity:

> *Professor 2: "so… the students are very interested… so, […] an indicator is the launch of the Master. When we announced the Master, we received almost two hundreds applications from students who wanted to attend the Master. Hence, this was a good indicator."*[457]

Another metric would be measurable through online platforms, websites or LMS used in connection to the instruction project.[458] Also regarding the "questions from students" metric of the indicator, in the ISIS module on dual-use and security issues in neurosciences, the engagement and interest by the students was included in the evaluation. Metrics included participation to the two live distance sessions and of each student posting questions in the course's online forum.[459] Twenty-two out of twenty-five students attended at least one of the two live sessions; while nine students attended both. Five students posted questions on the forum.[460]

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[456] Even before looking at what students have written as examples and answers to the activity in their notes, which would be a way to evaluate Level 2, Learning.

[457] Translated from the original French: *Professor 2: "alors… les étudiants sont très intéressés… donc, […] un indicateur c'est l'ouverture du Master. Lors ce que on a annoncé l'ouverture du Master, on a eu près de que deux cents demandes, d'étudiantes qui veulent intégrer le Master. Alors, ça c'était un bon indicateur."*

[458] For example, the EUBARNet project included a website used, inter alia, to promote the seminars series conducted in partner universities for life sciences students. As Mancini and Fasani (2012b) noted, EUBARNet website accesses from each country increased in the two-weeks period around the seminar in that same country, hopefully (but reasonably) indicating students and their local professors seeking for information.

[459] It should be noted that students were incentivized by that participation criteria would constitute one third of the final mark for the module, so in a way achieving Level 1 also became part of Level 2 objectives. This was anyway designed in the specific learning objectives for Level 2, which included awareness raising.

[460] Level 1 indicators for this example focused on quantity of participation, while qualitative feedback from students were not collected.

8.2.3 Drivers for achieving reaction indicators

More detailed opinions from interviewed educators may provide suggestions on what may raise the interest of students in issues of biosafety and, especially, biosecurity. Indeed, it seems that students are rarely engaged by the topics at first, as Professor 1 notes:

> *GMM: do you think they were interested, engaged, by the subject?*
>
> *Professor 1: "er, at first, at first, not, not necessarily, because they do not understand what that's really about."*[461]

And that anyway students do not see it as engaging as other, possibly more technical, areas:

> *Professor 9: "[for them to be] 'happy' I see things that they really enjoy doing… I mean, doing this thing rather gets them curious, I mean, I don't see them as active on this type of topic to tell they are strongly…[but] there is absolutely not a refusal…"*[462]

Interestingly, there is quite an agreement among interviewed professors on what stimulated positive reactions from students about this education and that, I think, confirms the importance of investing in the learning-by-design and learner-centred-delivery pillars discussed earlier in the thesis. Firstly is that teaching methods, particularly learner-centred, are more important than content to reach Level 1 objectives, as has been observed by different professors:

> *Professor 5: "the… communication must be more interactive, otherwise they will be there… watching the slides… this is just… more contents for…*
>
> *GMM: so you don't think it really depends on the subject?*
>
> *Professor 5: no."*

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[461] Translated from the original French: *Professor 1: "er, au début, au début, pas, pas nécessairement, parce-que ils ne comprennent pas de quoi se traite en réalité".*

[462] Translated from the original Italian: *Professor 9: "per happy io vedo delle cose dove loro si divertono molto a farlo… cioè, facendo questa cosa li incuriosisce, cioè, non li vedo così attivi su questo tipo di argomento da essere giudicati come fortemente… non c'è assolutamente né un rifiuto…"*

Professor 1: "this depends on how education is done, how the course is done, if it is very interactive, if it is innovative, and creative, to push students to ask questions to themselves, not just to lecture, formal[ly], just to give them information, clearly it's not interesting, the information exists on the web, now it's not a problem"[463]

Professor 3: "because we mix it, to make it attractive, we make interactive learning, we do case studies, we ask the groups."

The second factor to improve reaction identified by interviewees is that *interest* is related to *relevance*, something discussed under the previous Chapters and preached by the learning-by-design pillar:

GMM: "Do you think that those students were interested by the topics raised on biosafety and biosecurity?

Professor 6: yeah, why not, because it relates to their daily life. And ultimately who is going to be affected? It is us, we all. Because… the way you put things across, because when you want to drill in something, you tell them that if you are not taking care in the lab, what you are throwing out, ultimately is going to be bound back on us. It is through the environment that it is going to come back to us […]

GMM: mmh. So, so you would say that what really raised their… attention… is…

Professor 6: yes

GMM: … making something directly related…

Professor 6: directly relevant"

[463] Translated from the original in French: *Professor 1: "ça dépende comme on fait la formation, comme on fait le cours, si est très interactif, si est innovatif, et créatif, pour amener les étudiants à se poser les questions, pas uniquement pour magistral, formel, juste lors de donner l'information, c'est pas intéressante justement, l'information elle existe sur le web, maintenant ce n'est pas un problème."*

Professor 7: "yes, relevance. They see… you can see even the benefit. Even if they are selfish [laugh]. Er… this is risk for them, I mean benefit for them. If you will say that, for example in patient safety. You are doing blah blah blah to save the patient. Maybe, maybe some people who are selfish will say 'bah', but now, they are seeing things which help others and help themselves. Protect themselves from being infected. Or being harmed."

Professor 9: "some interest… you have to push them a bit for them to understand that actually it concerns them, and that's why I think it's important to have an approach that keeps very close to the subjects that have been discussed… and that are close to the subject of the course, and not to the issue [of deliberate disease/biosecurity] itself".[464]

8.2 Level 2 – Learning

The second level of Evaluation looks at the achievement of intended learning by students. Indicators to measure are indeed the learning objectives set during Design, according to the planned cognitive domains and levels of learning. Tools for Level 2 Evaluation could include quite informal ones such as observation by instructors and their opinions after interaction with students and exercises completed during the course. In some cases, evaluation can be completed with self-assessment tools. In other cases, however, an informal and/or self-assessed evaluation may not be enough; this will depend on the "degree" component designed into the learning objectives.[465]

In the design of Evaluation, I have advanced a number of learning objectives as examples of Level 2 indicators, and corresponding metrics and data sources for their measurement, organized in four thematic areas in which capacity would have the potential to mitigate deliberate disease risks: (bio)risk management; laboratory biosafety; laboratory biosecurity; and dual-use and broader biosecurity. In this paragraph, some data from projects are illustrated to put in

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[464] Translated from the original Italian: *Professor 9: "un interesse… bisogna un po' spingerli perché capiscano che effettivamente li riguarda ed è per quello che per me è importante fare un approccio che sia molto vicino a delle cose che sono state discusse… e che sono vicino all'argomento del corso, e non all'argomento [della biosicurezza/abuso] in sé."*

[465] See Chapter 6 on the design of learning objectives.

practice proposed metrics and data, including assessment methods actually used in education initiatives for higher education students, such as multiple choice questions; self-assessments; open questions; and essay writing.

8.2.1 Risk management thematic area

Learning objectives set for the risk management thematic area include to define the AMP model; to define risk; to know factors that influence risk likelihood and consequence; to define biosafety and biosecurity; to apply mitigation measures based on risk assessment; to assess biorisk (characterization and evaluation); and to feel confident using the biorisk management approach. These learning objectives have been designed with specific cognitive domains, including knowledge and attitude, and levels of learning, from "know" to "analyse/evaluate".

Multiple-choice questions were used in Project 18 seminars with students before and after instruction that could be used to test the learning objective "define biosafety and biosecurity". The metric advances that a satisfactory achievement would be for students to at least distinguish the focus of biosafety on accidental risks versus the focus of biosecurity on intentional risks – regardless of the laboratory or broader context. Results from questionnaires are reported in Table 30. While a majority of students selected the "correct" definition for laboratory biosafety, it should be noted that the share of students identifying the correct option decreased from before to after instruction. A reason for this may be that during the seminars students have been introduced to the concept of biosecurity, of which they likely had no or lower previous awareness than of biosafety.[466] Finding out the biosecurity side of biorisks possibly led to confusion as in the post-instruction question some students changed their answers to options more precisely referring to laboratory or broader biosecurity rather than biosafety. This may actually be a positive outcome as introducing the concept of biosecurity is a learning objective itself under the laboratory biosecurity thematic area ("understand importance and rationale of laboratory biosecurity").[467]

[466] Something that would be in line with the general awareness and content mastery of students as discussed under Analysis (see Chapter 5).

[467] However, the specific Level 2 indicator to be measured in this case looked at the capacity of the student to distinguish between biosafety and biosecurity, and we can comment that seminars under

Table 30 - Project 18 results, pre- and post-instruction questions, Level 2 risk management evaluation

Indicator	Question – multiple choice	Results Pre	Results Post
Knowledge: Know: Define biosafety and biosecurity	Laboratory biosafety refers to:	Stud=453 N=579[468]	Stud=453 N=570
	Measures and policies for preventing the deliberate misuse of pathogens	25% (112)	35% (157)
	Measures for preventing theft and loss of pathogens	10% (45)	19% (87)
	Measures for preventing the unauthorized access to pathogens and toxins	30% (134)	21% (93)
	Measures for preventing the unintentional exposure to biological agents and toxins, or their accidental release	63% (287)	49% (220)
	Unanswered	0% (1)	3% (13)

After the course on basics of biorisk management for the class of Country C students, participants completed self-assessment surveys. Questions can be connected with six out of the seven learning objectives/Level 2 indicators in this area.[469] Results of self-assessment are reported in Table 31. In all cases except one ("know how to describe risk as a function of likelihood and consequence") all students agreed or strongly agreed that they achieved the designed learning objectives. The items where students felt more strongly to have learned were "know what the AMP model represents" and "know the difference between a hazard and a threat".

Project 18 did not appear to be as effective in this regard, and possibly some lessons plans or instructional materials could be improved for clarity.

[468] Some respondents selected more than one option thus the total numbers are higher that the number of respondents.

[469] As I would argue that the learning objective "assess biorisk (characterization and evaluation)" being a too high level of learning to be tested with such a metric.

Table 31 - Country C results, post-instruction self-assessment questions, Level 2 risk management evaluation

Indicator	Question	Class[470]	Avg
Knowledge: Know: define the AMP model	I know what the AMP model represents		
	Strongly Agree	80% (12)	4,8
	Agree	20% (3)	
	Neutral	0% (0)	
	Disagree	0% (0)	
	Strongly Disagree	0% (0)	
	Unanswered	0% (0)	
Knowledge: Know: define risk	I can described risk as a function of likelihood and consequence		
	Strongly Agree	53% (8)	4,4
	Agree	33% (5)	
	Neutral	13% (2)	
	Disagree	0% (0)	
	Strongly Disagree	0% (0)	
	Unanswered	0% (0)	
Knowledge: Know: Factors that influence risk likelihood and consequences	I can analyze the factors that contribute to risk characterization and evaluation		
	Strongly Agree	27% (4)	4,3
	Agree	73% (11)	
	Neutral	0% (0)	
	Disagree	0% (0)	
	Strongly Disagree	0% (0)	
	Unanswered	0% (0)	
Knowledge: Know: Define biosafety and biosecurity	I know the difference between a hazard and a threat		
	Strongly Agree	87% (13)	4,9
	Agree	13% (2)	
	Neutral	0% (0)	
	Disagree	0% (0)	
	Strongly Disagree	0% (0)	
	Unanswered	0% (0)	
Knowledge: Apply: Mitigation measures are based on risk assessment	I know the importance of doing a thorough risk assessment prior to implementing/evaluating mitigation control measures		
	Strongly Agree	73% (11)	4,7
	Agree	27% (4)	
	Neutral	0% (0)	
	Disagree	0% (0)	
	Strongly Disagree	0% (0)	
	Unanswered	0% (0)	
Attitude: Understand: Feel confident about using the biorisk management approach	I feel confident about using the biorisk management approach		
	Strongly Agree	27% (4)	4,1
	Agree	60% (9)	
	Neutral	13% (2)	
	Disagree	0% (0)	
	Strongly Disagree	0% (0)	
	Unanswered	0% (0)	

In the work with Country A University 1, students who attended the course on biorisk management had to take a formal assessment test compliant with their HEI's regulations. Metrics for the appropriate learning objectives/Level 2 indicators were hence designed and introduced in the course's paper-based test. Metrics and results for the risk management thematic area are reported in Table 32. Students were presented with a true/false question on the difference between biosafety and biosecurity, which all students in the class answered correctly. The second example is an open question in which students were asked to describe the AMP model for biorisk management: the "degree"

[470] Where 1 is "strongly disagree" and 5 is "strongly agree".

component for this metric was to mention the three phases of assessment, mitigation and performance, with additional marks for explaining how they were connected. Almost all students got more than 50% of the mark for the question, however with an average of only 7,7 points out of 10.

Table 32 - Country A University 1 results, post-instruction test questions, Level 2 risk management evaluation

Learning objective	Question	Type	Marks /Total	Students over 50% of the mark	Avg marks/student
Knowledge: Know: Define biosafety and biosecurity	Biosafety refers to preventing accidental exposure to biological materials, while biosecurity often refers to theft or intentional access by unauthorized people.	True/False	2/69	100%	2
Knowledge: Know: define the AMP model	Explain and describe the AMP model for biorisk management and its components.	Open question	10/69	90%	7,7

8.2.2 Laboratory biosafety thematic area

Designed learning objectives for the laboratory biosafety thematic area include: to know the hierarchy of laboratory biosafety controls;[471] to understand advantages and disadvantages of laboratory biosafety controls; know decontamination, sterilization and disinfection; to recognize safe and unsafe work practices; to wash hands correctly; to select PPE; to don and doff PPE; to classify and segregate biological waste; and to evaluate the appropriateness of operational, facility and management risk mitigation measures. Importantly, the empirical data I have available from projects of education to students only allow providing examples of Evaluation on some of these learning objectives/Level 2 indicators. In particular, the research lacks Evaluation data on "skill" cognitive domains learning objectives that are particularly important in laboratory biosafety (though examples of Evaluation of two "skill" objectives is included through self-assessment questions). This is certainly something where further research would be important, possibly testing and leveraging some of the Level 2 metrics and data proposed under Chapter 6 also for "skill" objectives not evaluated here. Nonetheless, below I present evidence on, mostly, "knowledge" indicators in the "know", "understand" and "apply" levels of learning.[472]

[471] See Chapter 3 for a discussion on risk mitigation measures and controls.

[472] Also note that, as discussed under Chapter 3, capacities under the laboratory biosafety thematic area would probably only indirectly impact factors influencing likelihood and/or consequences of deliberate disease risks, suggesting that for this research the other three areas are a more important focus.

Answers to self-assessment questions from Country C students, based on pre-designed learning objectives for the course they attended, suggest that students felt strongly that they achieved the learning objectives on laboratory biosafety. The whole class either agreed or strongly agreed on achieving the indicators; the item receiving most support was "I am able to wash hands properly" (see Table 33).[473]

Table 33 - Country C results, post-instruction self-assessment questions, Level 2 laboratory biosafety evaluation

Indicator	Question - Self assessment	Class[474]	Avg
Knowledge: Know: Hierarchy of laboratory biosafety controls	I can categorize various mitigation efforts into the hierarchy of controls		4,7
	Strongly Agree	73% (11)	
	Agree	27% (4)	
	Neutral	0% (0)	
	Disagree	0% (0)	
	Strongly Disagree	0% (0)	
	Unanswered	0% (0)	
Knowledge: Understand: Advantages and disadvantages of laboratory biosafety controls	I understand the various categories of control measures used to reduce risk and their advantages and limitations		4,7
	Strongly Agree	73% (11)	
	Agree	27% (4)	
	Neutral	0% (0)	
	Disagree	0% (0)	
	Strongly Disagree	0% (0)	
	Unanswered	0% (0)	
Knowledge: Know: Decontamination, sterilization, disinfection	I know the difference between disinfection, decontamination, and sterilization		4,6
	Strongly Agree	60% (9)	
	Agree	40% (6)	
	Neutral	0% (0)	
	Disagree	0% (0)	
	Strongly Disagree	0% (0)	
	Unanswered	0% (0)	
Knowledge: Understand: Recognize safe and unsafe work practices	I am able to recognize potential unsafe work practices and conditions		4,6
	Strongly Agree	53% (8)	
	Agree	47% (7)	
	Neutral	0% (0)	
	Disagree	0% (0)	
	Strongly Disagree	0% (0)	
	Unanswered	0% (0)	
Skill: Understand: Washing hands correctly	I am able to wash hands properly		4,8
	Strongly Agree	80% (12)	
	Agree	20% (3)	
	Neutral	0% (0)	
	Disagree	0% (0)	
	Strongly Disagree	0% (0)	
	Unanswered	0% (0)	

[473] It may be useful to note that, while the course did not include any formal Evaluation for "skills" learning objectives (assessment tests with simulations or practical exercises), the course did include simulations and practical exercises during Implementation of instruction for both "skills" learning objectives (washing hands and segregate waste) that received very high self-assessment rates in this Level 2 Evaluation. This reinforces the idea that Development and Implementation needs to be appropriate for the cognitive domain and level of learning of learning objectives; if this is the case, it will be reflected in higher impact in learning.

[474] Where 1 is "strongly disagree" and 5 is "strongly agree".

Indicator	Question - Self assessment		Class[475]
Knowledge: Apply: Select PPE	I know which types of PPE are appropriate for different settings and risk levels		4,5
	Strongly Agree	43% (6)	
	Agree	57% (8)	
	Neutral	0% (0)	
	Disagree	0% (0)	
	Strongly Disagree	0% (0)	
	Unanswered	0% (0)	
Skill: Apply: Classify and segregate biological waste	I can classify and segregate different types of biological waste		4,7
	Strongly Agree	73% (11)	
	Agree	27% (4)	
	Neutral	0% (0)	
	Disagree	0% (0)	
	Strongly Disagree	0% (0)	
	Unanswered	0% (0)	

The final assessment test taken by Country A University 1 students included three questions to evaluate Level 2 indicators in the laboratory biosafety thematic area. One question asked to list the five categories of mitigation measures, select one and explain its advantages and disadvantages: all students successfully remembered the categories (the “know” level of learning component of the assignment), but only half of the class successfully explained pros and cons (the “understand” level of learning component of the assignment). With a second question, we wanted the student to recognize a piece of PPE and infer which routes of exposures it would provide protection on. It tested a higher level of learning, “apply”, as it required students to take what they learned into a situation similar, but different, from what we had discussed in class. This was the metric where the class performed worst.[476] A third question asked to identify unsafe practices from a list of laboratory work practices, a metric for a “knowledge: understand” learning objective in which almost the whole class performed excellently.

[475] Where 1 is “strongly disagree” and 5 is “strongly agree”.

[476] In this case, the question showed a picture of a N95 mask. Students remembered that a N95 mask would protect from the inhalation route of exposure better than other masks (something we had discussed in class), however most students forgot that the mask would provide protection not only against the inhalation route but also against the ingestion route. Hence, this metric would suggest that students achieved the learning objective on PPE only until a “know” or “understand” level of learning, but many are not yet able to “apply” their selection capacities to new situations, which is the required degree of the designed indicator.

Table 34 - Country A University 1 results, post-instruction test questions, Level 2 laboratory biosafety evaluation

Learning objective	Question	Type	Marks/Total	Students over a 50% of the mark	Avg marks/student
Knowledge: Understand: Advantages and disadvantages of laboratory biosafety controls	Please list the 5 categories of biorisk mitigation measures. Select one of them and state the advantages and disadvantages.	List	5/69 for the list	100%	5
			5/69 for the adv and disadv	50%	2,6
Knowledge: Apply Select PPE	For what route(s) of exposure would this piece of PPE below provide protection?	Recognise with picture	2/69	25%	1,2
Knowledge: Understand: Recognize safe and unsafe work practices	Which items below are NOT good laboratory work practices?	Recognise from a list	5/69	90%	3,9

8.2.3 Laboratory biosecurity thematic area

Learning objectives/Level 2 indicators included: to understand the importance and rationale of laboratory biosecurity; to complete a biosecurity risk assessment; to know methods for establishing physical security; and to use information protection methods. As noted for the laboratory biosafety thematic area, I do not have empirical data from projects to provide examples of Evaluation of all of these learning objectives; however, I think it's important to consider the Design of Evaluation including learning objectives beyond those discussed in this paragraph, that could contribute to capacities with the potential to influence risk likelihood and/or consequence.[477] Examples on Evaluation are presented here on two learning objectives of the "knowledge" cognitive domain and the "know" and "understand" levels, based on data from Project 18 and Country C experiences. Students from Project 18 were presented with a multiple choice question on laboratory biosecurity (see Table 35); the "correct" answer is the one statement that is not true on *laboratory* biosecurity, i.e. that "it comprises policies and practices that require life scientists to consider the ethical, social and legal implications of their work", as this would pertain to the broader concept of biosecurity under the next thematic area. Similarly to the

[477] Furthermore, the laboratory biosecurity thematic area may well include additional objectives than the examples presented under Design, including specific ones under the physical security, transport security, material control & accountability, information security and security awareness pillars discussed in Chapter 3.

question discussed above from Project 18 seminars' students, less students after the instruction selected the "correct" answer.[478]

Table 35 - Project 18 results to pre- and post-instruction questions, Level 2 laboratory biosecurity evaluation

Indicator	Question	Results Pre	Results Post
Knowledge: Understand: importance and rationale of laboratory biosecurity	Which statement about laboratory biosecurity is NOT true?	Stud=453 N=457[479]	Stud=453 N=466
	It comprises policies and practices that require life scientists to consider the ethical, social and legal implications of their work	47% (212)	44% (200)
	It comprises measures and policies against the theft and loss of pathogens	21% (95)	21% (95)
	It comprises measures and policies against the unauthorized access to pathogens and toxins	12% (54)	18% (80)
	It comprises measures and policies that seek to prevent the intentional release of pathogens and toxins	20% (92)	14% (62)
	Unanswered	1% (4)	6% (29)

Students from the class of Country C, based on Level 2 indicators relevant for the course they attended and the laboratory biosecurity thematic area, self-assessed that they learned (see Table 36) both on the "importance of laboratory biosecurity and the reasoning behind it", and on "different methods for establishing physical, information, and transport security" (with stronger agreement on the former learning objective).

[478] Again, we can argue that such a result may be due to the introduction of the biosafety/biosecurity dichotomy to students, who likely are not aware of the latter or used the terms interchangeably before instruction. While the value of introducing the biosecurity considerations to students is to be recognized, these results suggest that instructional materials from some of the seminars could have been clarified regarding the specificity of (laboratory) biosecurity. This consideration should be taken with precautions though: Project 18 was a networking undertaking that covered a number of seminars in different countries, using different formats (both traditional and learner-centred), different languages and focusing on different thematic areas. It wouldn't be fair hence to dismiss those seminars with criticism only based on comparison with other project experiences that were focused on specific countries (like Country A University 1, Country C, or Pakistan projects) or that involved smaller numbers of courses and students (like EUBARNet), furthermore considering that the primary goal of Project 18 was "raising awareness" at the very foundational level rather than building specific capacities, and specifically on dual-use and broader biosecurity rather than on the laboratory components of deliberate disease risks management.

[479] Some respondents selected more than one option thus the total numbers are higher that the number of respondents.

Table 36 - Country C results to post-instruction self-assessment questions, Level 2 laboratory biosecurity evaluation

Indicator	Question - Self assessment	Class[480]	Avg
Knowledge: Understand: importance and rationale of laboratory biosecurity	The importance of laboratory biosecurity and the reasoning behind it		4,8
	Strongly Agree	71% (10)	
	Agree	21% (3)	
	Neutral	0% (0)	
	Disagree	0% (0)	
	Strongly Disagree	0% (0)	
	Unanswered	0% (0)	
Knowledge: Know: methods for establishing physical security	Different methods for establishing physical, information, and transport security		4,6
	Strongly Agree	57% (8)	
	Agree	43% (6)	
	Neutral	0% (0)	
	Disagree	0% (0)	
	Strongly Disagree	0% (0)	
	Unanswered	0% (0)	

8.2.4 Dual-use and broader biosecurity thematic area

Learning objectives and Level 2 indicators for the dual-use and broader biosecurity thematic area proposed under Chapter 6 on Design include to know the prohibition norm on deliberate disease; to identify potential dual-use and broader biosecurity issues; to know actions to take when faced with a potential misuse ethical dilemma; to apply/analyse options to manage dual-use and broader biosecurity issues; to be aware of the responsibilities on dual-use and broader biosecurity and feel ethically accountable; and to document and justify decisions as appropriate. As for cognitive domains, they are five “knowledge” and one “attitude” objective, and they go from the “know” to the “evaluate” levels of learning. There is quite a wealth of data from the research that could be applied as examples to measure the metrics also suggested in Table 27 in Chapter 6. The largest attention to this thematic area, with respect to the other three, should not be surprising given the focus of the research on deliberate disease risks education *within* biorisk management education. The empirical work provides data from tools including post-instruction multiple-choice questions; self-assessments; and essay writing both directly collected and reported by interviewed professors. I don’t have data from a tool like “review of research work, proposals and reports” that I suggested to measure the metric especially for the higher level learning objective, “document and justify decisions as appropriate” which would look at if and how the student evaluates options on managing dual-use and broader biosecurity issues. However, such an indicator and metrics should be kept in mind as important ones in this

[480] Where 1 is “strongly disagree” and 5 is “strongly agree”.

thematic area, and ones that critically bridge learning with Level 3, behavioural transfer.

The post-instruction questionnaires of the courses for students organized in the framework of the Pakistan and EUBARNet projects shared several questions on this thematic area. Questions were designed as metrics for the indicators on knowing the prohibition norm on deliberate disease and on identifying dual-use and broader biosecurity issues. In both projects, the absolute majority of students demonstrated having become aware both about legal international prohibition measures on deliberate disease (even if some confuse between the specific prohibitions of the Geneva Protocol and of the BTWC), and on the concept of dual-use (see Table 37).[481]

Table 37 - Pakistan and EUBARNet results, post-instruction test questions, Level 2 dual-use and broader biosecurity evaluation

Indicator	Question	Pakistan	EUBARNet[482]
Knowledge: Know: the prohibition norm on deliberate disease	Which was the first International treaty to prohibit the use of toxic and biological weapons?		
	The Hague Declaration, 1907	6% (1)	4% (6)
	Geneva Protocol, 1925	56% (10)	46% (78)
	Biological and Toxin Weapons Convention, 1972	39% (7)	21% (36)
	Chemical Weapons Convention, 1993	0% (0)	1% (1)
	Unanswered	0% (0)	2% (4)
Knowledge: Understand: Identify potential dual-use and broader biosecurity issues	What do you understand by the term “dual-use” in the life sciences?		
	The uncertainty on results characterizing new technologies	0% (0)	2% (4)
	The potential of obtaining positive results beyond expectations	11% (2)	1% (1)
	The possibility that they are applied both for peaceful and hostile purposes	89% (11)	88% (150)
	The ambiguity of life science and technology	0% (0)	9% (15)
	Unanswered	0% (0)	1% (1)

The Level 2 evaluation tools in those projects also shared self-assessment questions and one opinion question (see Table 38). Large majorities of students from seminars in both projects thought their knowledge and understanding was developed on the BTWC; the history of biological weapons; the problem and

[481] The first question was designed as a metric for a “know” learning objective, so it asked content in the same form it was presented during instruction; nonetheless, it was a bit “tricky” as it assumed attention from students between the prohibition on use of the Geneva Protocol and the absolute prohibition of the BTWC. The second question was designed as a metric for an “understand” learning objective, so it presented options paraphrased from which it was presented in class. Answers are in line with what found by pre-2011 experiences using similar questionnaires (Mancini and Revill, 2009). See Chapter 6 for the discussion on the levels of learning objectives and the difference between “know” and “understand” levels.

[482] For the first question respondents from five seminars as the question was not included in the post-instruction questionnaire used by the University of Milan.

risks of dual-use; and tools and policies of biosecurity.[483] A question asked students if, after attending the seminar, they thought some aspects of the science they study could present dual-use issues (a metric of the "attitude" learning objective "being aware of the responsibilities on dual-use and broader biosecurity and feel ethically accountable"). A large majority of EUBARNet seminars students replied they didn't see dual-use issues in their research, with only 24% answering affirmatively (in the Pakistan seminar class, of a smaller number of students, the answers where evenly divided). Post-instruction questionnares for students of the seminars organized in the framework of Project 18 also resulted in a majority of students self-assessing that their learning in this thematic area improved.[484]

However, using such direct questions as metrics cannot measure the correctness of the answer (i.e. if the students' research or field of science actually has dual-use issues they should recognize), but rather that the student considers the topic. Furthermore, such a metric could only partly evaluate a learning objective of the cognitive learning domain of "attitude" and a level of "understand" or "apply" (that requires the student to re-elaborate the concept or translate it to new situations). An alternate or additional option may be to include multiple-choice questions with no simple or univocal answers. For example Project 18 post-instruction questionnaires asked, "what are important things to remember about dual-use", with the possibility to select different options. Students selected a range of equally relevant statements, but the one that clearly got the relative majority of preferences was that "life scientists should be aware of the social, ethic and legal implications of their work".[485] However to capture the necessary nuances and elaborations from students on the "attitude" indicator, the best strategy may be to include open questions or spaces for students to comment. Indeed comments by EUBARNet students in the questionnaires suggest that some of them were led to "becoming aware of the responsibilities and feeling ethically accountable". One student for example noted the necessity to *"think always about the subjects of the research, to have*

[483] The strongest feedback from EUBARNet students being regarding the history of biological weapons, on which over 80% replied "yes" or "very much"; and the lowest regarding tools and policies of biosecurity, on which 60% thought their knowledge and understanding was developed.

[484] 56% of 453 respondents replying "yes" to "I learnt about dual-use, misuse and security issues".

[485] With 49% per cent of the selections. More than one selection was possible.

an autonomous opinion, which may be moral and ethical" [EB.01], and others underlined the role of education to make risk mitigation stronger and more relevant: "*I think it's necessary to develop the culture of responsibility and a strong ethical protocol among life scientists. In my opinion it's important to include programmes like (and stronger that) this one, in scientific curricula to rise the knowledge of potential dual use and biological weapons and to train people, that will become scientists, to biosecurity awareness"* [EA.07]; *"All the knowledge means power, and everything can be used for good or bad issues, it's just the way of thinking and your principles. So in order to avoid a hostile application work should be done in the basic level = changing the way people think*". [EC.03]

The challenges for evaluating Level 2 as designed indicators move from testing mere "knowledge", in the same form it was presented to higher levels (testing "application" to new a situation or "analysis" and "evaluation" to construct and assess new concepts) are recognized also by professors interviewed regarding their experience in implementing education on deliberate disease risks. Indeed Professor 9 reports that they were able to evaluate, formally, learning objectives for the "know" level of learning, and confirmed that students achieved it regarding knowing what dual-use is. However, at the same time they recognized that learning objectives on dual-use should really aim at the "apply" and higher learning levels. They were not able yet to develop materials or evaluate learning at those levels, as their description illustrates, but their ideal metrics would include some elaboration by the student:[486]

> *Professor 9: "Er… from that point of view the idea… at least, compared to when I start the course when on dual-use they have no idea, they never heard of what we're talking about… when I ask this question, they <u>know</u> it. And so… anyway, on that I would say that from a point of view… really the most <u>basic</u>… [laugh] that we couldn't go below of… at least the idea… that concept, you are aware of it… I would say <u>yes</u>. Really with… it's not a question that they skip, or… <u>they do answer it</u>, they answer correctly and that's it. If we try to go further, the limitation I see… regarding to… what is the <u>ideal</u> competence that… I would like to*

[486] Note how Professor 9 is clear about the differences between a "know" capacity and higher levels of learning, and that they need different materials and evaluation to be developed.

achieve… it would be, that when confronted with a case, they would be able to… understand it, interpret it, or react to it, if one tells them 'you are in this situation' or 'you got three options, which ones actually presents…', I mean, something more as, by the way, I already do for the rest of the course, I do not give them the same example again that I used in class, but I put them in front of a completely new case and I evaluate how in front of this new case they are able to read it, to interpret it… on the rest of the programme I do it, on this topic… I don't have enough examples, myself, to be able to first train them, and second check them. And so, at the end… what I think is failing, but not it's not the students' fault, it's mine, is… if we go on one example… it's a just a tale they would tell me… and they wouldn't be able to go beyond the simple tale… but that's because I didn't train them beyond the example of the specific case… so I am able to reach awareness, but on the efficacy should they find themselves in a situation of this type, I'm afraid it wouldn't be enough."[487]

Discussions with educators also highlighted how metrics beyond formal tests may be useful to gain information on the "apply" or "analyse" objectives, for example observing that students ask questions during the courses relating their new awareness on dual-use to their work, as Professor 8 observed:

[487] Translated from the original Italian: *Professor 9: Er… da quel punto di vista l'idea… almeno, rispetto a quando io li prendo a lezione che il dual-use non ne hanno idea, non hanno mai sentito di cosa ne stanno parlando… quando io faccio questa domanda, lo sanno. E quindi… comunque io su quello direi da un punto di vista… proprio quello più basic… [ride] credo al di sotto non si possa andare… l'idea almeno… quel concetto lì ce l'hai presente… direi sì. Con grande… non è una domanda alla quale non rispondono, non fanno… rispondono, rispondono in modo giusto e bon. Se si cerca di andare oltre, il limite che io vedo… rispetto a… qual è la competenza ideale che… mi piacerebbe poter raggiungere… sarebbe davanti a un determinato caso, che loro fossero in grado di… capirlo, di interpretarlo, o di reagire, se uno gli dice 'ti trovi davanti a questa situazione', o 'tu ne hai tre di questo tipo qua, qual è quella che presenta effettivamente…', cioè qualcosa in più come faccio per il resto del corso, dove non gli rifaccio lo stesso esempio che ho fatto a lezione, ma li metto davanti a un caso completamente nuovo e lo valuto che davanti a questo caso nuovo, loro sono in grado di saperlo leggere, di saperlo interpretare… io sul resto del programma lo faccio, su questo… non ho abbastanza una casistica, io stessa, per poter uno allenarli, e due fare la verifica. E quindi, alla fine… la cosa che ritengo ma non per colpa degli studenti ma per colpa mia, fallimentare…. Se si va su un esempio… è una storiella che mi raccontano… e oltre la storiella non riescono ad andare… ma perché io non li ho allenati oltre l'esempio del caso specifico… perciò io riesco a raggiungere la consapevolezza, sull'efficacia se dovessero trovarsi in una situazione di questo tipo qua, temo non sia sufficiente.*

Professor 8: "and… you know, some of them started, you know… relating to what research they are going to do…

GMM: that's very interesting

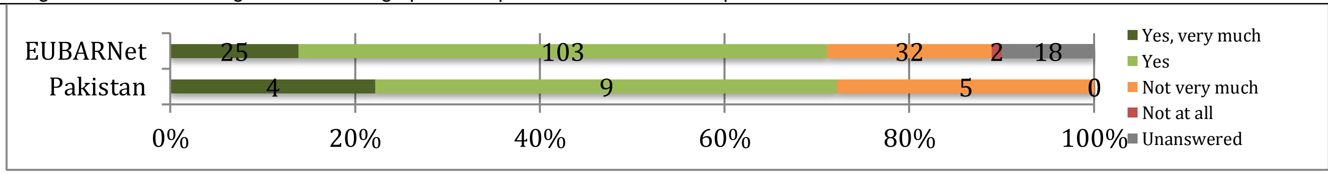
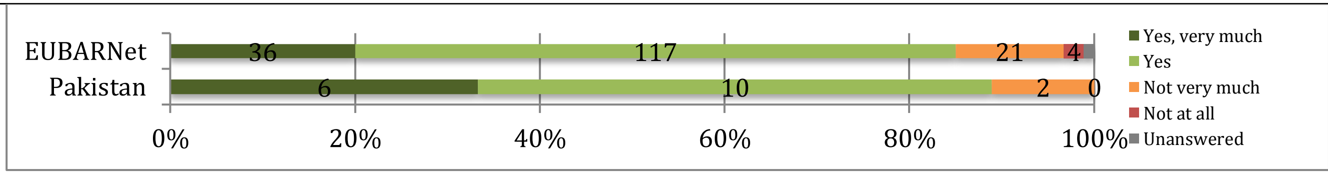
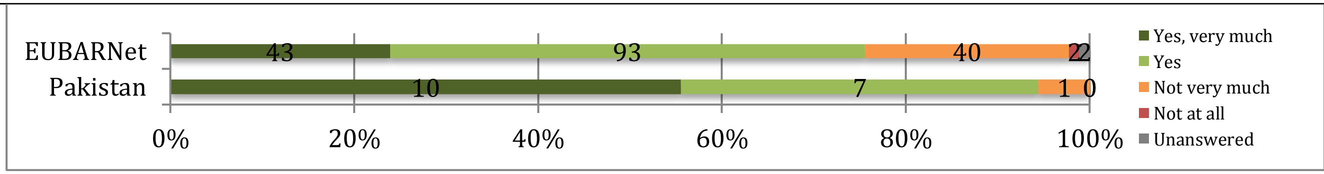
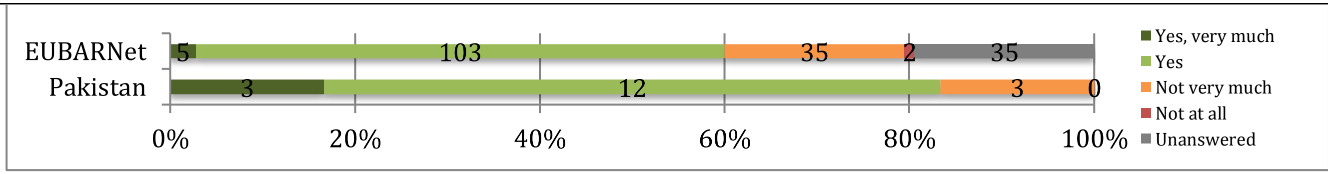
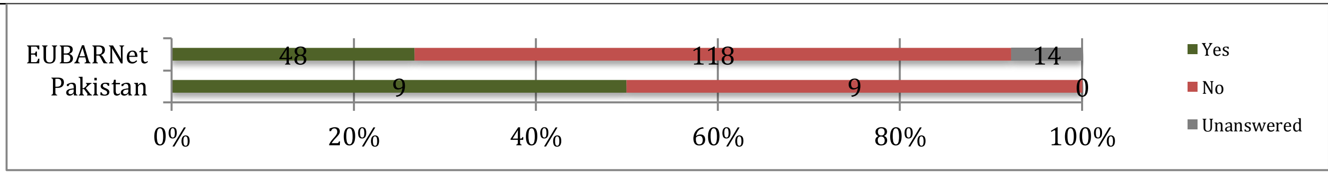
Professor 8: you know, and they… started asking questions, 'how am I supposed to do with this', and 'how can I do it', just because… they have… gotten that… so it means they are relating to ideas to what they are going to do, and they are seeing… the… class… the lessons are important."

Or as Professor 9 thinks regarding a debate they stimulated in their classes on publishing-versus-not-publishing research with dual-use issues:

Professor 9: "…er… well actually often there are discussions exactly because… there is no consensus… so that… exactly because there is an argument and an evolution… and by the way I… we were talking before of test questions on this thing… it's not… there is not the right answer. I mean, I… try to get as many arguments as possible and that one is able to practice their discussion there… so that while definitions and stuff… that, let's say, has its own formats, with the case then we leave it exactly to say that there are… some positive aspects, some negative aspects, and some risk factors and how can you… and the pre… the majority let's say is always in favour of publishing..."[488]

[488] Translated from the original Italian: *Professor 9: "… er… beh in realtà spesso ci sono discussioni proprio perché… non c'è l'unanimità… per cui…proprio perché c'è una argomentazione e una evoluzione… e tra l'altro io… parlavamo prima delle domande di esame su questa cosa… non è… non c'è la risposta giusta. Cioè io… cerco di far venire più argomentazioni possibili e che uno sia in grado anche lì di esercitare la sua discussione… perciò mentre la definizione, le cose… quello diciamo ha una sua formalizzazione, nel caso dopo lo si lascia proprio per dire che ci sono… degli aspetti positivi, degli aspetti negativi, e dei fattori di rischio e come si riesce a … la pre… la maggioranza diciamo è sempre a favore della pubblicazione…"*

Table 38 - Pakistan and EUBARNet results to post-instruction self-assessment questions, Level 2 dual-use and broader biosecurity evaluation

<table>
<tr><td>Indicator</td><td>Question</td><td></td></tr>
<tr><td></td><td colspan="2">Do you think that your knowledge and understanding of the following specific aspects have been developed after this seminar?</td></tr>
<tr><td>Knowledge: Know: prohibition norm on deliberate disease</td><td>The Biological and Toxin Weapons Convention</td><td>
</td></tr>
<tr><td rowspan="2">Knowledge: Understand: Identify potential dual-use and broader biosecurity issues</td><td>History of Biological Weapons</td><td>
</td></tr>
<tr><td>The problem and the risks of “dual use”</td><td>
</td></tr>
<tr><td>Knowlegde: Apply/Analyse: options to manage dual-use and broader biosecurity</td><td>Tools and policies of “biosecurity”</td><td>
</td></tr>
<tr><td>Attitude: Understand/Apply: be aware of the responsibilities on dual-use and broader biosecurity and feel ethically accountable</td><td>After attending the seminar, do you think that some aspects of research that you study could present a “dual use” issue?</td><td>
</td></tr>
</table>

In developing the Level 2 evaluation tools for the module on dual-use and militarization issues in neurosciences in the ISIS Master experience, we indeed used the form of short essays for students as a better way to not only evaluate lower level indicators but potentially also objectives of the “apply”, “analyse” and “evaluate” levels of learning. Students had the freedom to choose between two themes for their assignment of a one thousand words essay. The first assignment was titled “Position of your country in the international conventions on chemical, biological and toxin weapons”, while the second assignment “Case study on dual use and militarization potential, and possible measures to prevent misuse and risks”. Each assignment was evaluated against two metrics: knowledge and research, i.e. the ability to, following the class discussion, find information and references on national positions in the international prohibition regime; and critical thinking, i.e. the capacity to illustrate and defend options to manage dual-use and security issues. While the correspondence was not strict, the first metric focused largely on learning objectives of “know” and “understand” levels (the students could repeat some notions and facts presented in class, and describe them in their own words); and the second metric focused largely on higher levels of learning (the students were expected to select a case or a field, identify potential issues, propose options to manage them and justify their decisions).[489] Students performed well on the essays, with an average of 83 points out of 100 for the metric on “know” and “understand” indicators, and slightly lower at 79 out of 100 for the metric on “apply/analyse” and “analyse/evaluate” indicators. However, the large majority of students chose the first theme, confirming the challenge in moving from lower to higher levels of learning (see Table 39).

[489] Both assignments should have shown achievement under both metrics, but the first assignment had more room for the first one, while the second had more potential for the critical thinking bit. The evaluation of the essay constituted two thirds of the mark for the module. Students were presented with all this information and the evaluation strategy; the essays were independently evaluated by two lecturers (myself and a researcher from BDRC).

Table 39 - ISIS Master results, post-instruction assessments, Level 2 dual-use and broader biosecurity evaluation

Assignment	N students	Indicator	Metric Knowledge and Research		Indicator	Metric Critical Thinking	
			Avg.	Median		Avg.	Median
1	20	Knowledge: Know: the prohibition norm on deliberate disease	84	84	Knowlegde: Apply/Analyze: options to manage dual-use and broader biosecurity	78	78
2	5	Knowledge: Understand: Identify potential dual-use and broader biosecurity issues	80	83	Knowledge: Analyze/Evaluate: Document and justify decisions as appropriate	84	87
Tot.	25		83	83		79	78

Some students considered and discussed the options of committees that evaluate risks and benefits of projects under the ethical perspectives including dual-use potential. Students who were evaluated well on the first essay reported national positions in the CWC and the BTWC, the existence of national legislation, as well as in some cases historical cases they found of dealing with chemical and/or biological weapons during the XX century. Essays received higher points if they demonstrated understanding of the international prohibition norm as well as of the importance of its universality. Regarding the second theme, students who excelled presented examples of dual-use issues in neurosciences, and of militarization issues, including for improving and degrading performance. They found and referred appropriate references within and beyond what was discussed in class.[490]

8.3 Level 3 – Behaviour

Under the design of Level 3 Evaluation, I proposed some indicators and metrics to assess if learning was sustained over time and space and translated to behaviour. Indicators included, for example, that students perform actual risk assessment in real situations; proper separation in laboratory fridges; following good safety practices; integration of biorisk management considerations in scientific work; integration of biosafety and biosecurity considerations in the design of new facilities or organizations; questions raised to supervisors regarding biorisks in their work. Not surprisingly, considering the challenges of evaluating Level 3 discussed in Chapter 6, university professors often struggle

[490] It should be noted that discussions in faculty meetings revealed this was the only written essay required to these students in the semester. According to faculty members it was a very useful exercise for their own students to practice academic writing.

with these indicators. However, interesting suggestions may come from interviewed professors who had the occasion to observe behaviours of students who took education on biorisks and deliberate disease risks management. Some professors reported plans, ideas and practices of behavioural evaluation strategies that I also considered as inputs in designing the proposed Level 3 evaluation tools, such as to look at considerations given by students to biosafety and biosecurity once they will start being responsible for a research project or managing a laboratory; or integrate formal and informal assessment tools at planned intervals after instruction, as Professor 7 suggests:

> *Professor 7: "So… the <u>first</u> thing in my opinion is that, we will <u>ensure</u> that… new generations of lab technicians who are going to work in the labs, they know about these things. So they can easily understand, when they make standard operating procedures, or when they say, strictly… if they are becoming for example a <u>manager</u> of a lab, when you'll become… the … he has, he has a concept so he will become, for example, he can say from the beginning, 'why there is no guard in the lab, in the door of this? This is against the rules' […] I want to arrange with the technician labs, of biosafety that… we have first year, we have second year. You know, ok? What I am planning to do is that… to make observation. […] What is the difference in their… behaviour regarding this? […] The other issue is that, we want to compare between <u>these</u> students in the second year, and the first year students. Who have spent now about one year… in their behaviour, in their, I mean, dealing with the lab. […] In order to make it… objective rather than subjective […]"*

Certainly interviewed professors seem to share the idea that behavioural change depends on learning, that learning depends on education, and that a formal education may be more powerful than an informal one, supporting the value of evaluating Level 3, as Professor 1, Professor 7 and Professor 9 made quite clear:

> *Professor 1: "and, I think that's the same thing, education is fundamental, education is fundamental.*
>
> *GMM: mmh*

Professor 1: in changing people's behaviours."[491]

Professor 7: but… I think now… the hope is in the scientists, in the students, will be scientists, technicians. In the future. So, from the start, since they are students, we will implant these concepts in their mind. […] They should not think that intentionally… people are good, nobody will do…. No, keep in your mind that. It might be… one day, somebody will take this, theft, abuse, release intentionally, anyhow, so… once they know, er, the concerns that have to take in mind, they will take action.

Professor 9: "in my opinion, it does have an influence. Because, when things have been institutionalized, they anyway matter more. So it may be true that in the short term you don't exactly do everything that you were told, but anyway it sits in a box in your brain, and so…the fact of… or, in a longer term of reviewing it, rethinking to it, or coming back to it… in my opinion it does have an effect. […] that maybe after time it may come back. Or... trigger something. I think it's very different… with not having received an education, or an education in which someone told you something somehow but it never was institutionalized…"[492]

Regarding empirical data, certainly Professor 1 reported observation of different behaviour regarding laboratory biosafety and biosecurity practices among Master students that took education introduced by one of the projects, compared to previous students who were not exposed to such education, when they had the opportunity to observe those students who proceeded to PhD:

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[491] Translated from the original French: *Professor 1: "and, je pense que c'est la même chose, la formation est fondamentale, la formation est fondamentale.*

GMM : mmh

Professor 1: dans le changement des comportements des individus."

[492] Translated from the original Italian: *Professor 9: "secondo me una influenza lo fa. Perché, quando delle cose sono state istituzionalizzate acquisiscono comunque un peso maggiore. Perciò magari è vero che sul momento non fai esattamente tutto quello che ti è stato detto, ma comunque rimane [in] una casella del tuo cervello, e quindi… il fatto… o a più lunga scadenza di rivedere, o ripensarci, o ritornare… secondo me un effetto ce l'ha. […] che magari a distanza di tempo può anche tornare. O… far scattare qualcosa. Secondo me è molto diverso… tra non aver ricevuto una formazione o una formazione che qualcuno ti ha detto così ma che non è stata istituzionalizzata…"*

Professor 1: "there are few students who have benefited of this information, but I know that some of them who have accessed to PhD studies […] And I, er, I see that their behaviours are different […].

GMM: actually one of my questions is exactly that, behaviour. You know, you teach something to students, you want the students to know something […] but then you also have behaviour. And you said 'I see their behaviour is different…'

Professor 1: it's different

GMM: do you mean from others?

Professor 1: I mean the use, the use of solvents, how they manipulate the chemicals, how they protect themselves, so behaviours are very different. Very different from other students who have not taken that course."

Despite this example however, there are not enough data and reports from educators to measure many of the specific metrics I have advanced under Design, especially for practical behaviours under the laboratory biosafety and laboratory biosecurity thematic areas. On the other hand there are several mentions by professors of instances relevant to Level 3 indicators such as increased consideration of risks by students; students looking for more information; and students raising new questions to instructors and supervisors. So Professor 3 and Professor 8 report cases of students identifying biosafety or biosecurity problems and raising them to themselves or other faculty members:

*Professor 3: "We had an event where we talked about this. My teachers, my colleague faculties, mine and in other universities, these sometimes complain, "oh you raised too much awareness, now the students <u>ask</u> us", the… for example the waste disposal in the lab, 'oh, what are we doing? This *** is having… a ****** ******* and this makes us cancer, so why are we discarding it like this?'"*

Professor 8: "… it changed them somehow… because, the first lot, there was a student, who… you know, when he enters the lab, he starts *commenting on certain things, like ‘oh, I think this one… are we supposed to do like this?’. So… if he remembers… are we supposed to do like this or are we supposed to…”*

GMM: yeah, yeah… I understand what… and so… you have seen something like that, from students who took that course… er… and it’s a different behaviour than students that never had […]?

Professor 8: yeah… er… okay, particularly for this one who took it… I was, I was with them… but now, even… other students, like I called this one bachelor of … even if they don't name it as… <u>biorisk management</u>… but somehow it is <u>tucked</u> in there…”

On the other hand, Professor 4 was positive in describing change in the behaviour of students especially in considering issues under the dual-use and broader biosecurity thematic area:

Professor 4: “…what we see is an increased interest in our students to discuss problematic aspects of research… […] now we see a much bigger willingness to identify risks and to discuss them. So we have sort of opened their mind to see problematic views of projects that... they couldn't see before… […] now we get lots of good suggestions, and good views which makes me think that maybe we did help them in doing this, and I think we gonna move… […] previously as I said [it was] ‘we don't see any ethical problems’, now they all sit down and do that individually, now we get <u>lots</u> of good suggestions, and good views which makes me think that maybe we did help them in doing this…”

Furthermore, consider the opinion from this student who participated in one of the EUBARNet seminars and then wrote an article for the University’s student magazine:

“as a young and naive student I found the seminar overwhelming. These were questions I had not stopped to ask myself. I was upset by the thought of politicians regulating research and censoring science. I believe the wish to explore the world a foundation of research, and sharing information an irreplaceable part of development. Realizing that there is a

potent risk that scientific research be exploited and misused makes me insecure. Maybe we need better guidelines." (Sandell, 2012).

Interviewed professors also recognized the challenges in designing and measuring Level 3 evaluation tools, including that they have to be structured to allow comparability but flexible enough to consider variance among learners, with different students achieving behaviours in different ways and at different times, and that observing behavioural change is a long-term process, which may be challenging in a higher education context:

Professor 6: "yes, that is again in the individual, responses are different. Because some people are very very receptive, and again… it's not that I will say, again there is a degree of change or impact, I would say will vary. It will vary. One person may be really be more conscious, maybe putting it to practice, another will just… you know, ignore it."

Professor 4: "it's of course very much based on individuals here…

GMM: …have you noticed any difference in behaviour?

Professor 4: oh, that's very difficult. We have… we have, with this… continuous, very thorough project, and I am talking about now that we have courses with goals and so on, we haven't gone that far, so I think maybe two years or something like that."

Furthermore as we discussed under Level 2 evaluation, the goal and the challenge is to push students to higher levels of learning, so that they transfer into behaviour not only consideration and awareness, but actually develop critical thinking and assessment capacities:

Professor 4: "…and I think we gonna move… er… the problem that we have seen so far is that it is quite, a lot of… thinking, I think this and I think that… so, we need to have that a more arguing and a more professional way, and I think that is something we have to work on, it's not just personal views, although they are important. You have to argue for your case and also bring in some good general arguments, so some students forget those, they just tell us what they think. And we need to *have them in a more professional attitude, to also argue for projects and cases, and problems that may be related to what they are doing."*

Another challenge, that we have discussed in theory under Design regarding setting learning objectives, is if the risk management aspects that are being targeted for improvement do not really depend on training, or if they are not only training problems. If there are other problems besides the lack of capacities of students, it may be more difficult that learning achievements are translated into behavioural ones. Professor 6 makes the example of supervisors and managers needing to be role models for students to facilitate the creation of behaviour based on learning; and Professor 9 argues that students have to find an environment welcoming the biorisk and deliberate disease risks management knowledge, attitudes and skills to be able to transfer them. The danger is for students not to be able to initiate a change, and eventually even becoming complacent to unsafe and un-secure practices. Along the same line may be read the argument by Professor 7 to educate and train in parallel both students and current staff, to avoid that when educated students enter the labour market find an un-conducive environment on safety and security:

Professor 6: "… you know, and I have to be the role model also, for them to <u>learn</u> things. If I am doing it in the wrong way, I cannot think that my students will do that. […] Ok, so I have to <u>tell</u> them.

GMM: yeah. And, and, <u>act</u>…

Professor 6: <u>act</u>, yes"

Professor 9: "…to put in practice… it's one of the things in these cases, it's that perhaps the student knows it, but then when he is in a laboratory and the senior, or who supervises him, let's say, 'oh well, but you really don't need to do this and <u>that</u>', then he doesn't have the strength… […] Because… actually in this transition phase… the student then is in a too weak position. He cannot be the one who…

GMM: who maybe changes a decision…

Professor 9: …he does not have the… he is not equipped, he does not have the chance to do it, so maybe he gets it… we should, 'do you realize that you're not working in the right conditions?'… maybe he does. […] …but if the laboratory itself, because it does not have the equipment or because it is not in the conditions, the student is not in the position to be able to… have an influence […]"[493]

Professor 7: "[…] The other issue is that… what we are going to do with the people who are already… in service training. We have to make tailor-made courses for them. Upgrade their skills in this, so that… when… the newly graduated people enter to that level market, there will be a harmony with the people…

GMM: yeah

Professor 7: … no conflict. They are… speaking with a common language. […] we want to apply that, nobody is allowed, nobody will say 'what you are doing, we are twenty years working like this, and nothing happened'…"

8.4 Level 4 - Result

Levels 4 of Evaluation looks at the broader result or impact of education; in case of managing biorisks, and specifically deliberate disease risks, we look at results on risks after education is implemented.[494] Opinions and experiences reported in the interviews confirmed that education has the potential to impact on risk, and that evaluation on this Level would be challenging to quantify or

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[493] Translated from the original Italian: *Professor 9: "… mettere in pratica… è una delle cose in questi casi qua è che magari lo studente lo sa, però quando si trova in un laboratorio e che il senior o chi lo segue, diciamo, 'figurati mica hai bisogno di fare questo e quell'altro', quello non ha la forza… […] Perché… in realtà in questa fase intermedia… lo studente dopo è in una posizione troppo debole. Lui non può essere quello che…*

GMM: che cambia una decisione magari…

Professor 9:… non ha il… non è attrezzato, non ha la possibilità di farlo, perciò magari se ne rende conto… bisognerebbe, 'ti rendi conto che non stai lavorando nelle condizioni giuste?'… magari lui ce l'ha. […] … se però il laboratorio stesso comunque perché non ha le attrezzature o perché non è nelle condizioni o non ce le ha, non è lo studente che è nella posizione di poter… incidere […]"

[494] Achievement of results would be dependent on students reaching learning (Level 2) and sustaining it to behaviour (Level 3), and expected results should be consequential to learning and behaviour objectives as planned during design of education.

qualify, but nonetheless possible, as the reasoning by Professor 5 and Professor 9 suggests:

> *Professor 5: "when… maybe when they link to the society… to the industry, to the pharmaceuticals…[…]… I am sure they can pass, the scientists or the educators can pass to the industry areas, or to define an area."*

> *Professor 9: "…that would remain as all your experiences, that for good and bad anyway shape your personality and what you can do. So… I think things are measured on a time span that is much longer and so we will never be able to have tangible data, if not indirect indicators, on the fact that some accidents don't happen which means that at the end in some way you achieved the effect."*[495]

Professor 9's point on indicators for Level 4 is in line with the specific evaluation tools I proposed during Design. Those indicators for Level 4 included the availability of risk mitigation measures; reduction of LAIs, cross-contamination, or environmental release; reduction of thefts, breaches, or losses; and a well-established norm on the prohibition of misuse of science and material. Besides the mention of incidents and accidents quoted also by Professor 9, Professor 7 mentioned the reputation of the organization and the availability of biorisk mitigation measures:

> *Professor 7: "I think, one of them as you said, incident reports. Er, frequency, er, if there is outbreaks, as you said… and… the other issues that… also the reputation of, of the lab… if I feel that… the work of the lab become[s] better… specially in… that means its, I mean, service it's improving […] The other issue I think that, I can, I can ask technicians who work in this lab, and the other labs. Specially… if they… er… if they*

[495] Translated from the original Italian: *Professor 9: "… che rimanga come tutte le tue esperienze, nel bene e nel male comunque plasmano la tua personalità e quello che riesci a fare. Perciò… io penso che le cose si misurano su un arco di tempo che è molto più lungo e quindi noi non riusciremo mai ad avere dei dati che siano tangibili, se non indicatori poi indiretti, sul fatto che non si verifichino certi incidenti che fa sì che poi alla fine vuol dire che in qualche modo l'effetto l'hai ottenuto."*

were working in this and they were transferred or by any… so to give us, er, like comparison."

Level 4 Evaluation extends over time - even more than behavioural observations - possibly beyond the period when students remain in the university. So as noted in Chapter 6, different methods could be needed to observe results of education, such as alumni networks that allow contacting and surveying graduates in their different workplaces and careers. Furthermore, faculty members point out that education of technical students is a necessary but often not sufficient condition to reach desired Level 4 indicators. Professors identified other conditions that should be present or built,[496] to make sure learning and behaviour can actually translate to results, such as general awareness; appropriate regulation and legislation; and an oversight system and structure which scientists and science educators can confidently interact with:

Professor 1: "They are three things that go together. Zero risk does not exist, […] but they would help in reducing risk the most, so they are education, training; awareness raising, the largest, general; and then regulation

GMM: yeah I like this, the three strands, and levels. Awareness raising…
Professor 1: for the majority of population…

GMM: …general. Knowledge and education, especially for those people in those specific roles…

Professor 1: yes, yes

GMM : and regulation

Professor 1: regulation, yes […] you must go with the three together. Because as it is often members of parliament or politicians don't make regulations, because themselves are not competent. Because it's not scientists who make policies, decisions rest on policy, it's not scientists. […] so this thing of going on the other side to do the war, the war in Syria,

[496] And that may be considered in the web of prevention of deliberate disease risks.

or… this is… because of this a control is really needed… [unclear]… laws are also needed"[497]

Professor 9: "[…] to be able to have… that the system controls itself… there must be a diffused awareness… but then when problems come out there must be interfaces to reach to."[498]

Also as Professor 9 reinforces regarding potential threats, education of young and future scientists is needed to have the awareness and the necessary capacities to identify and understand biorisks; but then the scientific community - yet autonomous in their risk identification responsibilities - cannot alone manage all deliberate disease risks. Structures to contact, and which can provide guidance or assistance, are needed:

Professor 9: "[…] however at some point, once you understood and you don't know… because it's difficult to assess… if it is a real risk or not… not necessarily, right? Not everyone who has risk behaviours en up… […] to on the one side understand that there is a radicalization problem… and maybe this is the information part, but the next step is who do I turn to."[499]

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[497] Translated from the original French and English: *Professor 1: "Sont trois choses qui vont ensemble. Le risk zero n'existe pas, […] mais seront réduire au maximum du risque, donc c'est l'éducation, la formation; la sensibilisation, la plus grande, générale; et puis la règlementation*

GMM : yeah I like this, the three strands, and levels. Sensibilisation…

Professor 1: pour la majorité de la population

GMM : general. Knowledge and education, especially for those people in those specific roles…

Professor 1: yes, yes

GMM : and regulation

Professor 1: regulation, yes […] you must go with the three together. Parce-que de façon-ci parfois les parlementaires ou les politiciens ne font pas de règlementation, parce-que eux-mêmes, ils ignorent. Parce-que ce sont pas le scientifiques qui font les politiques, la décision reste on politique, ils ne sont pas les scientifiques. […] Donc ce fait de aller de l'autre coté a faire la guerre, la guerre en Syrie, ou… ça c'est… pour ce là il faut même qu'on contrôle… [unclear]… il faut des lois aussi. "

[498] Translated from the original Italian: *Professor 9: "[…] per riuscire ad avere… che il sistema di autocontrolli… ci deve essere la consapevolezza diffusa… ma dove poi dopo sorgono i problemi ci devono essere le interfacce con le quali rapportarsi."*

[499] Translated from the original Italian: *Professor 9: "[…] Però a un certo punto, tu una volta che hai capito e non sai… perché è difficile capire… se è un vero rischio o meno… non è detto, no? Non è che tutti quelli che hanno dei comportamenti a rischio finiscono… […] da un lato capire che c'è un problema di radicalizzazione… e forse questa è la parte di informazione, ma l'atto successivo è a chi mi rivolgo."*

After considering the consensus on the potential for education to influence result, the consistency of indicators, and views on the other conditions that have to be integrated into the web of prevention, we should look at how can education actually mitigate deliberate disease risks; and at the suggestions from empirical data using the evaluation tools proposed.[500]

An important discussion before looking at measurements of Level 4 indicators is the different risk characterization and evaluation by different professors among the deliberate disease risk scenarios. In particular, I collected different opinions regarding the non-state threats, and between the insider and outsider non-state threats. The likelihood of deliberate disease risks waged by non-state actors, such as bioterrorism, is often characterized as low likelihood by professors. Some educators clearly think that the possibility of insider threats involving scientists, i.e. that science students could become compromised in the future and hence that education would have a role in limiting that risk via inculcating a norm against those actions or increasing the changes that the *other* scientists mitigate it, is improbable. See the comment from Professor 5:

> *Professor 5: "they have a project together […] they want to have the private sectors also involved. […] So, I am guessing if they work together in a project, more related to organisms or bacteria, or fungi or something, er… I am sure they can pass, the scientists or the educators can pass to the industry areas, or to define an area… more about this… precautions, and procedures… it's hard for me to believe that someone intentionally would do this, but they would be certainly be more aware if they worked together…"*

[500] I argued in Chapter 3 that results of education in the four thematic areas have the potential to impact in the three deliberate disease risk scenarios. In the first scenario, characterized by the state threat, education would influence risk through the ability of scientists to recognize the offensive nature of a program and reducing their willingness and availability to being employed in a biological weapons program. In the second risk scenario, characterized by the non-state outsider threat, education would influence risk through, for example, improved and more relevant physical security and good practices on material control & accountability; responsible management of dual-use material and research; capacity on laboratory biorisk management measures; and freeing-up resources for R&D on public health by saving on prescriptive risk mitigation measures. In the third risk scenario, characterized by the non-state insider threat, education would again influence risk through some of the above capacities, but also via, for example, scientists being able to recognize insider threats, and the instilled norm of prohibition of deliberate disease in the individual and scientific community.

However, other educators think the likelihood of the non-state insider threat deliberate disease risk actually exists and that it should be considered. This position sustains the role of education within deliberate disease risks mitigation, which may involve an insider threat with scientific capacities. Besides the quote above from Professor 9, also consider the reasoning from Professor 1:

> *Professor 1: "[…] we have the problem with chemical products. […] so… controlling chemical products that get out of the Faculty, that are used during practical classes, that are used during… we remain vigilant on this products so that a student never… they can be very quickly manipulated, unfortunately we see it with… with what's going on in the Middle East… and so many young people who rapidly diverted from their… they are very easily manipulable… Some, who have difficulties maybe… that are psychological. Not everyone, some."*[501]

Regarding empirical or potential results on Level 4 indicators highlighted in conversations with educators, firstly I would count mentions of biorisk mitigation measures being implemented and promoted by students as a result of their behaviours after the educational interventions. Improvements according to the "available risk mitigation measures" indicator also has the potential to impact on indicators such as reduced LAIs, cross-contaminations, and environmental releases. See for example Professor 6's reports of improved hazardous material control & accountability, and Professor 8's quotes on biological waste management:

> *Professor 6: "So… those students who are working with something which is… dangerous… which has some potential… [they] can take care of it. Ok? Sometimes certain things happen in ignorance… you may not… want to do it, but it happens. Because of… lack of awareness… So, there, the education is important so that the person at least… if… deliberately somebody does it, that's a different story. […] But… something should*

[501] Translated from the original French: *Professor 1: "[…] nous avons le problème avec les produits chimies. […] donc… un contrôle des produits chimie qui sort de la faculté, qui sont utilisés pendant les travaux pratiques, qui sont utilisés dans… on est vigilantes pour ces produits parce-que qu'on jamais un étudiant… qui peut être manipulés très rapidement, malheureusement le voit avec le… avec le qui se passe en Moyen Orient… et donc beaucoup des jeunes qui sont rapidement détournés de leur… ils sont très facilement manipulable…. Certains, qu'on des difficultés, peut être… qui sont psychologiques. Pas tous, certains."*

not happen because of just ignorance. So, there comes the role of the education in security. Like, in my lab, we are not dealing with something that can be dangerous, ok? But we do work with pathogens, which are of mild nature, but you know after this… this workshop, I told them to… you know, catalogue things, there is a… somebody opening the minus twenty, puts a sign of what they have taken, what they have kept… so that, at least they can recall it. If there is a something missing, I am doing it for that purpose, how much is that thing used, whether it's there, in our possession or not, simply because that… the same thing can be applied, in situations when you are dealing with the most deadliest things."

Professor 8: "Because he is already conscious about it, and if you explain, it means he takes it. Because at the first time they are not interested, you finish class, maybe you finished the class two months ago, and… he, by the time they finish they are starting their research, then someone comes to the… and asks particular questions. You know? Ok, for example I can tell you that… […] so I came to this lab before… somehow there's a way they were disposing [waste] […]"

The potential for education to impact specifically on the results regarding security has also been recognized, as Professors 7 and 4 infer:

Professor 7: "can insure people who are shy of this that… within five years, six years, things will be changed. We will have new qualified technicians, who are well provided theoretically and they are conceptual for work regarding security, is different from others. So, they can make, they can make change. Towards this more… security…"

Professor 4: "I think there's just raising the question and saying, this might be a problem, makes them talk among each other, 'what are we doing and why are we doing it', and I like to think that is one of the best ways to actually secure our environment and the things they are doing, because we can't lock [all] doors, and we can not be in full control of what they're doing"

A more general argumentation by Professor 4 regarding results touches on promoting and improving risk-informed practices. They also reprise a theme underlined by other interviewees, that ignorance is a risk itself and becomes a risk factor for deliberate disease, and that the educational action could help in mitigating both:

> *Professor 4: "so just having you know groups of students talking to each other, 'what are we doing and how are we doing it', I think is <u>really</u> important. And if we lowered sort of the… er… some of them think it's a little bit ridiculous to talk about risk, 'we know what we are doing', and some teachers actually have that attitude too, that… how to… explain, 'how dangerous could it be for us to modify a bacteria?' and so on, so they say 'we know about the risks' and so on, so I think this attitude that 'we know what we're doing' is…er… sometimes sent over to the students that there are no risks, and I think <u>that</u> is a risk. If they don't understand that what we are doing constantly, actually raises risks, and that the students among themselves talk about, you know, 'could it be dangerous for us', or for me or for you…"*

Other educators reinforce this concept, less generally on risk and more specifically on deliberate disease risks. Results they argue would be relevant for the Level 4 indicator of promoting a "well established norm of prohibiting misuse". Clearly we devote particular attention to this area, as it is especially relevant to the deliberate disease risks focus within the biorisk spectrum. The mechanisms in which implemented education would mitigate deliberate disease risks are, firstly that young and future scientists are not easily compromised due to ignorance and become insider threats themselves; and secondly by creating a safeguard and group stewardship among the community of scientists against future insider and outsider threats:

> *Professor 1: "ignorance is much more dangerous than knowledge.*
>
> *GMM: mmh*
>
> *Professor 1: er, ignorance it's much more dangerous because if there is no knowledge, the whole group does not have knowledge. And so it's the whole group that can be manipulated much more easily. On the other hand, if they have knowledge, there is one from the group who can*

become disloyal and who can be manipulated, but it's not the whole group. Because what is dangerous is ignorance. More dangerous is really ignorance, it's not… […] For example, [unclear] because they [grew up] in ignorance, of religion's truth, […] etcetera etcetera etcetera, or simply of the true [unclear], with weak understanding, and actually the look for [utopies], for things that… because, actually, it's ignorance, because if they really knew religion […], they would not do this. [laugh] Because this is not religion… it's not… it's no religion…

GMM: it's much closer to ignorance

Professor 1: ignorance, exactly."[502]

Particularly in view of the former mechanism, given the long-term and close relationships that are created among students and between students and educators, higher education could be a valuable context to assess the potential for insider threats, and possibly to address them before they concretize in deliberate disease risks:

Professor 1: "when I take a student in the PhD, there isn't more than, there isn't more than his knowledge, than his brain, his behaviour, his communication, his vision, more or less these are the things I am interested in. So besides what I am aware or not on if he is a good technician or a good [unclear] or what, and so with the relationship over three years, over four years, we'll see how he behaves, and so a student who risks… be it what it takes with him, of material, or that he does not

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[502] Translated from the original French and English: *Professor 1: "l'ignorance est beaucoup plus dangereuse de que la connaissance.*

GMM : mmh

Professor 1: er, c'est beaucoup plus dangereuse l'ignorance parce-que s'il n'y a pas de connaissance c'est tout le group qu'il n'a pas de connaissance. Et donc tout le group qu'il peut être manipulé beaucoup plus facilement. Par contre, si ils ont la connaissance, c'est un du group qui peut virer infidèlement et qui peut être manipule, mais il n'est pas tout le group. Parce-ce que ce qu'est dangereuse c'est l'ignorance. Plus dangereuse c'est vraiment l'ignorance, c'est pas la… […] Par exemple, [unclear] parce-ce qu'ils sont [grandis] dans l'ignorance, de la vérité de la religion, […] etcetera etcetera etcetera, ou simplement de la vrai [unclear], du faibles psychologique, en fait ils cherche des [utopies], des choses… parce-que, en fait, c'est l'ignorance, parce-ce s'ils connaitraient vraiment la religion […], ils ne vont pas faire ça. [laugh] Parce-que ça c'est pas la religion… c'est pas… c'est aucune religion…

GMM : it's much closer to ignorance

Professor 1: ignorance, exactly"

do what he should, normally… is rejected at some point. A student who risks becoming other things, we are also going to exclude him."[503]

On the other hand regarding the latter mechanism, the result of "well established norm of prohibiting misuse" emerging from education would limit deliberate disease risks especially in both the outsider and insider non-state threats scenarios giving future scientists the tools to identify risks in their technical areas and contexts (as well as, particularly in the outsider non-state threat scenario, helping future scientists not to inadvertently raise deliberate disease risks):

> *Professor 9: "on this specific risk…education is very important for awareness, and so to obtain of course first so that you in the first place don't do something dangerous with dual-use, and so self… restrain yourself. And this is one aspect. And then because to be able to… no regulation, policy system… is able to control everybody… I mean, it's not like… it would be crazy to think… and so to get that… that the system self-controls… diffused awareness must be there… […]"*[504]

Finally, the result of education measured by the "well established norm of prohibiting misuse" indicator would provide future and young scientists with the capacities to identify and assess deliberate disease risks (either from insider or outsider threats) faster and more clearly, as well as to communicate them:

> *Professor 9: "well from a certain point of view, and also in this case… I very much make the comparison to what happened now with terrorist acts… because… because we don't have other options to defend*

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[503] Translated from the original French: *Professor 1: "quand je prends un étudiant en Doctorat, il n'y a pas que, il n'y a pas que son savoir, que son cerveil qui m'a, son comportement, sa communication, sa vision plus ou moins ça fait les sont qui m'on intéressent. Donc au de là que je sais ou pas qu'il est un bon technicien ou bon [unclear] ou ce là, et donc avec la relation sur trois ans, sur quatre ans, on voit comment il se comporte, et donc un étudiant qui risque de… soit qu'il ne prend pas soi, de tout le matériel, ou qu'il ne faut pas qu'il faut faire, normalement… le rejet à un certain moment. Un étudiant qui risque de dévier de autres choses, on va il exclure aussi."*

[504] Translated from the original Italian: *Professor 9: "su questo rischio specifico… l'education è molto importante per la consapevolezza, e quindi per far acquisire assolutamente uno per non fare tu stesso sul dual-use qualcosa di pericoloso, e quindi auto… frenarti. E questo è un aspetto. E poi perché per poter… nessun sistema di regulation, di policy… è in grado di controllare tutti… cioè non è che… non sta né in cielo né in terra questo… e quindi per riuscire ad avere… che il sistema di autocontrolli… ci deve essere la consapevolezza diffusa… […]"*

ourselves, if not general awareness and that when in front of given behaviours one can… more in advance… identify that potentially there is a problem. If that means to have as it can be in some cases, there could be in some cases some central offices where you can send a warning, where it's possible to… so there can be a feedback on the warnings, it's one of the things that I can imagine could be a trace… er… and in this case I would probably need that level [of competence]. Because if I have… then I can spot behaviours which are not right."[505]

8.5 Conclusions

Examples of evaluation of reaction of students to education suggest that objectives for Level 1 were achieved by actions in the considered projects. According to the proposed indicator, students were generally "satisfied, interested and engaged" with educational interventions. Metrics to support it are particularly measured from post-instruction questionnaire surveys, where 90% or more of students were interested in the topics and thought that the quality of instruction was high. Feedback also suggested that students thought that education on biorisk/deliberate disease risks was particularly relevant for their position, country, and scientific formation; and that they favoured learner-centred-delivery approaches, as those described in Chapter 7, rather than more traditionally lecture-based formats.

Empirical data from considered projects and experiences of interviewed professors, suggest that students in the four thematic areas generally achieved testable learning objectives/Level 2 indicators to acceptable degrees. Some learning objectives were more easily achieved than others. It is easier to evaluate lower levels of learning, on which I have presented a range of possible evaluation tools. Particularly in the dual-use and broader biosecurity thematic area, being aware of and understanding the dual-use issue is a basic learning

[505] Translated from the original Italian: *Professor 9: "beh da un certo punto di vista, e anche in questo caso…io faccio molto il parallelo con quello che è successo adesso con gli atti di terrorismo…perché… perché noi non abbiamo altre possibilità per difenderci, se non la consapevolezza generale e il fatto che di fronte a certi comportamenti uno…con più anticipo… è in grado di identificare che c'è potenzialmente un problema. Se quello vuol dire avere come può essere in alcuni casi, possono essere in alcuni casi delle centrali dove si può segnalare, dove si possa… allora si può avere un riscontro sulle segnalazioni, è una delle cose che posso immaginare possa essere una traccia… er… e in questo caso probabilmente avrei bisogno di avere questo livello [di competenza]. Perché se io ho degli… riesco a vedere dei comportamenti che non sono giusti".*

objective that was achieved in the experiences that addressed it, which provide useful examples for evaluation tools. Evaluating indicators at higher levels of learning requires more complex evaluation strategies, however some ideas for evaluation tools for these levels have also been presented. The research was mainly able to evaluate indicators of the "knowledge" and "attitude" cognitive domains, while it lacks Level 2 evaluation data on the "skill" cognitive domain, although some ideas presented in this Chapter and the designed metrics and data sources proposed in Chapter 6 could remain valid.[506] Finally, it should be reminded how differences in students and their learning styles may influence the ways and rates in which they learn. As one interviewed professor noted – not least confirming the power of exercise, one of the principles of learning discussed in Chapter 7:

> *Professor 6: "[…] you have to… emphasize it once and again, it's not one go… there are, there are people, you know, in the group, who are very receptive in one go, that again depends on the sensitivity of the person, that will be individual attitude. So, some may take it immediately, others will need some more… you know, reaffirming the same thing over the time…"*

Interviewed professors shared the view advanced by this research's design and evaluation tools that behavioural change depends on learning, and that the latter depends on education. There are examples of observed behaviours in students who took education designed as a mitigation tool of deliberate disease risks, which were improved, compared to students who were not subjects of such programmes. These reports of empirical observations however are scarce especially for what regards the laboratory biosafety and laboratory biosecurity thematic areas, not least because structured evaluation tools for behaviour are lacking or because it's difficult to observe students some time after they

[506] Another aspect to highlight is any difference between experiences of instruction applying the learner-centred-delivery approach and those using a more traditional instructor-centred approach. Previous analysis on the post-instruction survey data from EUBARNet seminars (Novossiolova et al., 2013) for example compared learning results among seminars finding that students who attended the two seminars in the series with a higher degree of active learning (employing different collaborative learning formats, including TBL) showed a considerably higher percentage of correct answers to the question on defining the dual-use dilemma than students who attended the four seminars in the series with a higher degree of instructor-based lecturing.

completed a specific course. Other identified challenges include observing behaviours that implement higher levels of learning, and making sure that behavioural transfer is not prevented by non-training problems, such as a work environment that is not receptive to the awareness and capacities on biosafety and biosecurity that students acquired. On the other hand however, a number of the interviewed professors reported change related to increased consideration of risks, particularly regarding dual-use and broader biosecurity issues.

Evaluation of results seems to confirm that education of young and future scientists, specifically in the higher education context, has the potential to mitigate the risks of deliberate disease risks.[507] Furthermore, education has been defined a necessary but not sufficient condition to achieve risk mitigation, and educators reinforced the idea that components such as legislation and regulatory systems to support scientists in risk management should be integrated in the web of prevention of deliberate disease risks.[508]

Nonetheless, conversations with educators confirmed that tools proposed in Chapter 6 of this thesis could be useful to evaluate results on risks, as well as provided data that - although not representative – provide useful illustrations. These indicators include the availability of risk mitigation measures, where some professors reported improvements connected to students' behaviours emerging from education; reduced LAIs, cross contaminations, and environmental releases; reduction of thefts, breaches, or losses; and a well established norm among students of prohibition of misuse. The latter, which is deemed particularly relevant to mitigate the risks of deliberate disease within the biorisk spectrum, was frequently quoted in interviews with educators as a reasonable development promoted by education. Professors who had experience of promoting and implementing education with their students confirm the view that education would mitigate deliberate disease risks largely by affecting risk likelihood in the three considered risk scenarios, in line with what theorized in Chapter 3. According to the accounts of their experiences,

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507 Conversations with educators who implemented instruction indicated that empirical data are scarce due to the long-term nature of expected results and challenges in following-up with students after their academic formation.

508 In this regard, it could be interesting for further research to design and assess models of outreach between law enforcement and the scientific communities on a collaborative and open basis, on the line for example of the FBI-universities initiatives (Lempinen, 2011; AAAS, 2013), see Chapter 4.

education would have the potential to reduce the likelihood of future and young scientists of becoming involved in state programs of developing biological weapons (under the first risk scenario); reduce the likelihood of themselves becoming insider threats, and make them better able to identify and counter insider threats (under the third risk scenario); and mitigate the opportunity for outsider threats to misuse (under the second risk scenario) by improving scientists' awareness and capacities to protect their science and to identify and mitigate misuse risks.

9. Evaluation in instruction design plan

This Chapter will discuss Evaluation in the instruction design plan of research, applying the evaluation tools designed in Chapter 6. Data from the projects are presented and discussed on if and how instructional design based on the learning-by-design and learner-centred-delivery pillars have been useful in promoting effective and sustainable examples of education on deliberate disease risks. The discussion is based on indicators and respective metrics presented in Table 28. The Chapter starts from the reaction of participants in ISD workshops, moves to evaluating the achievement of learning objectives, followed by evaluation of the creation of actual instruction and of its formalization within higher education programmes, based on the experiences of the considered projects. That is, Level 3 and Level 4 evaluation in the instruction design plan whose indicators correspond to the Implementation component of ADDIE as discussed in Chapter 7.

9.1 Level 1 - Reaction

The first level of Evaluation in the instructional design plan measured the same indicator used in the education plan regarding students, but this time focusing on educators participating to ISD workshops. Hence the indicator "the participant is satisfied, interested and engaged" measured their reaction to the training aimed at promoting education on biorisk, and deliberate disease risks, management. The data to measure the indicator's metrics come from satisfaction surveys completed by participants after ISD workshops; other data from those workshops, as well as from interviews with professors.

Examples for measurement of satisfaction from post-ISD workshops surveys come from participants from projects in Region A, Country A University 2, Country B, Country C and Country D who participated to different ISD workshops. The surveys used one model already used for discussion in the previous Chapter and presented in Chapter 1, and used for trainings on biorisk management by Sandia National Laboratories.[509] The satisfaction indicator has been measured in three cases with both the "average score" and the "spread of support" metrics, and in two cases with only the "average score" (see Table 40). Feedback from instructors on ISD workshops have been positive or very

[509] It asked participants, anonymously, opinions on items to understand their satisfaction, interest and engagement, using Likert-scale questions.

positive, with all items receiving strong majorities of at least “agree” answers and/or average scores above 4 out of 5, and all participants from courses that used the “spread of support” metric evaluating the programme as relevant to their position.

Table 40 - Level 1 evaluation results from post-ISD workshops satisfaction surveys

	Region A		Country A University 2		Country B	Country C	Country D	
I am satisfied with the event/workshop								
Strongly agree	74% (17)		52% (15)				65% (13)	
Agree	26% (6)		41% (12)				30% (6)	
Neutral	0% (0)		7% (2)				5% (1)	
Disagree	0% (0)	4,7	0% (0)	4,4	4,3	4,8	0% (0)	4,6
Strongly disagree	0% (0)		0% (0)				0% (0)	
Unanswered	0% (0)		0% (0)				0% (0)	
This event/workshop met my prior objectives and expectations								
Strongly agree	57% (13)		24% (7)				45% (9)	
Agree	39% (9)		66% (19)				50% (10)	
Neutral	0% (0)		10% (3)				5% (1)	
Disagree	4% (1)	4,5	0% (0)	4,1	4,6	4,9	0% (0)	4,4
Strongly disagree	0% (0)		0% (0)				0% (0)	
Unanswered	0% (0)		0% (0)				0% (0)	
The ability, clarity and completeness of the trainer were adequate when responding to trainee questions								
Strongly agree	70% (16)		66% (19)				65% (13)	
Agree	26% (6)		34% (10)				25% (5)	
Neutral	4% (1)		0% (0)				5% (1)	
Disagree	0% (0)	4,7	0% (0)	4,7	4,6	5,0	0% (0)	4,6
Strongly disagree	0% (0)		0% (0)				0% (0)	
Unanswered	0% (0)		0% (0)				5% (1)	
The information I learned within the course was important and relevant to my current position								
Strongly agree	57% (13)		62% (18)				70% (14)	
Agree	26% (6)		21% (6)				30% (6)	
Neutral	0% (0)		0% (0)				0% (0)	
Disagree	0% (0)	4,7	0% (0)	4,8	-	4,3	0% (0)	4,7
Strongly disagree	0% (0)		0% (0)				0% (0)	
Unanswered	0% (0)		0% (0)				0% (0)	

Comments in open questions from participants tend to confirm the positive feedback on both the subject matter and the approaches to instructional design; and on the plans for transferring instruction to students, see for example:

> *“I have learnt new things that I will pass down in my future trainings” [RA.ISD.01]*

> *“Excellent training. Opened my eyes on methods of training skills I did not have prior knowledge on” [RA.ISD.02]*

> *“Implementation of this idea in many colleges in Country B and practical approach” [B.ISD.2.01]*

"It will help me in including some of the training/learning principles in my class" [C.ISD.05]

Participants' engagement in ISD workshops can also be evaluated through the metric of groups' involvement in learning activities. The indicator of the interest and engagement of educators can be assessed by the continuing participation of engaged individuals in subsequent projects on education on deliberate disease.[510]

In summary, engaged academics have generally been interested in the idea of learning and developing education for students, and advocates of the importance of teaching management of biorisks and deliberate disease risks to students. Another possible underlying motivation for increased interest by educators on education on these subjects, and on considering education as a possible risk mitigation tool, is proposed by Professor 9 in terms of risk perceptions and evaluation by educators:

Professor 9: "[…] it would be thought that the risk would only be from the south Mediterranean, and I have to say that the reinterpretation with what happened… with terrorist acts in Europe, carried however by Europeans, […] suggests… how… the importance of the theme within the European countries themselves, and not seen as a risk coming from the outside, gained a certain… er… it reinforced let's say an initial interest which was more of just curiosity."[511]

9.2 Level 2 – Learning

The second level of Evaluation in the instruction design plan focuses on the achievement of learning objectives by participating educators on designing effective education, according to the ISD principles. Proposed learning objectives/Level 2 indicators from Chapter 6 include: knowing the components

[510] It has been noted in the projects overview in Chapter 1 for example how members of the network of the 2008-2009 project "Fostering the Biosecurity Norm" then became promoters of the EUBARNet project in 2011-2012; and as they, as well as previously engaged professors in the Morocco and Pakistan projects, initiated the international network which constituted Project 18.

[511] Translated from the original Italian: *Professor 9: "[…] si pensasse che il rischio fosse soltanto proveniente dal sud mediterraneo, e devo dire la rilettura con quello che è successo… con atti di terrorismo in Europa, svolta però da europei, […] fanno capire… come… l'importanza del tema all'interno dei paesi europei stessi, e non visto come un rischio che viene da fuori ha trovato un suo… er… ha rinforzato diciamo un interesse iniziale più di curiosità."*

of the training design cycle; understanding what to look at to characterize learners and instructional context; drafting learning objectives; designing instruction; understanding different learner-centred instructional techniques; using learner-centred education development and implementation methods; and evaluating education's impacts on the four levels. The designed learning objectives include five in the knowledge and one in the skill cognitive domains; and span from the "know" to the "evaluate" levels of learning.

The projects provide data to measure some of the metrics included in the design of evaluation tools and organized in Table 28 in Chapter 6. Possible data sources include post-instruction self-assessment questionnaires by faculty members; evaluation questions on instructional design and development; rubrics for peer-review of instruction development and implementation exercises; developed instructional materials by professors participating in train-the-trainers programs; and interviews with educators involved in promotion of education on deliberate disease risks.[512]

Examples of answers by participants to post-ISD workshops self-assessment questionnaires in the framework of the projects with Region A, Country A University 2, Country B and Country D HEIs indicate that after the train-the-trainer programmes instructors generally felt confident on a number of key capacities related to phases of the ADDIE instructional design model. In Table 41, results from questionnaires are reported (with the spread of support and/or the average score metrics) for different self-assessment questions connected with the Analysis, Design, Development, Implementation or Evaluation phases of instructional design.

[512] Post-instruction evaluation questions to students can also be useful to understand if some instructional design principles have been applied in education they received. The questionnaire used in Project 18 seminars for example asked students if they were well informed about the objectives of the event, which can be useful to test the application of the Development principle of clearly stating objectives and developing in line with students' expectations (84% of the 453 students to Project 18 seminars on dual-use/deliberate disease risks at least agreed to the item).

Table 41 - Results to post-ISD workshops self-assessment questions, Level 2

Indicator	Question	Region A		Country A University 2		Count ry B	Country D	
Knowledge: Understand: what to look at to characterize learners and instructional context	I know what resources are available on biosafety, biosecurity and bioethics education							
	Strongly agree	-	-	45% (13)	4,3	-	65% (13)	4,7
	Agree	-		38% (11)			35% (7)	
	Neutral	-		14% (4)			0% (0)	
	Disagree	-		0% (0)			0% (0)	
	Strongly disagree	-		0% (0)			0% (0)	
	Unanswered	-		0% (0)			0% (0)	
Knowledge: Know: components of the training design cycle; Knowledge: Understand: different learner-centred instructional techniques	I know useful models from learning science that will make developing training easier and also more effective							
	Strongly agree	68% (15)	4,6	31% (9)	4,3	4,1	-	-
	Agree	36% (8)		62% (18)			-	
	Neutral	0% (0)		3% (1)			-	
	Disagree	0% (0)		0% (0)			-	
	Strongly disagree	0% (0)		0% (0)			-	
	Unanswered	0% (0)		0% (0)			-	
Knowledge: Apply: design instruction	I am able to select and use resources to configure educational materials for target audiences							
	Strongly agree	-	-	31% (9)	4,2	-	-	-
	Agree	-		62% (18)			-	
	Neutral	-		3% (1)			-	
	Disagree	-		0% (0)			-	
	Strongly disagree	-		0% (0)			-	
	Unanswered	-		0% (0)			-	
	I am able to match desired objectives with available resources							
	Strongly agree	-	-	41% (12)	4,3	-	55% (11)	4,6
	Agree	-		45% (13)			45% (9)	
	Neutral	-		10% (3)			0% (0)	
	Disagree	-		0% (0)			0% (0)	
	Strongly disagree	-		0% (0)			0% (0)	
	Unanswered	-		0% (0)			0% (0)	
	I am able to use validated instructional design processes to plan biorisk management training session							
	Strongly agree	59% (13)	4,5	-	-	4,1	-	-
	Agree	45% (10)		-			-	
	Neutral	0% (0)		-			-	
	Disagree	0% (0)		-			-	
	Strongly disagree	0% (0)		-			-	
	Unanswered	0% (0)		-			-	
Skill: Apply/Analyse: use learner-centred education development and implementation methods	I am able to design and practice brain-friendly activity to highlight an aspect of biorisk management							
	Strongly agree	45% (10)	4,4	-	-	4,4	-	-
	Agree	55% (12)		-			-	
	Neutral	5% (1)		-			-	
	Disagree	0% (0)		-			-	
	Strongly disagree	0% (0)		-			-	
	Unanswered	0% (0)		-			-	

However, self-assessment and multiple choice questionnaires alone often do not provide the necessary depth and resolution to measure achievement of instructional design learning objectives, especially those of higher levels of learning. Products developed by participants during ISD workshops on the other hand can be a powerful data source for metrics of the designed indicators. One example is the design documents produced by participants in which they at the same time practice the learning-by-design pillar and draft instruction on biorisk management for their students. Contemplating design documents by participants is a way to measure how training programmes were successful in achieving learning objectives on the Analysis and Design components of the ADDIE model of ISD. The data from actual design documents presented in Chapter 6 illustrate how participants achieved, to different degrees, the learning objectives of understanding what to look at to characterize learners and instructional contexts; knowing the components of the training design cycle; drafting learning objectives; and designing instruction. Similarly, the instructional materials on biorisk management that participants produced during training activities on the Development ADDIE phase (as described in Chapter 7), can be a data source to assess the achievement of the learning objectives understanding and using different learner-centred-delivery techniques. Professors participating to Region A and Country B projects, for example, practiced the instructional design pillars by producing learning activities for students. While again the quality of the products varied, they were useful evaluation tools to assess that participants at least improved and in many cases were successful in achieving those Level 2 indicators. Peer-review rubrics created during ISD workshops are another example of a useful tool for the evaluation of those learning objectives related to Development and Implementation, as well as an occasion for participants to improve on the learning objective related to the Evaluation skill. Table 42 reports results from two ISD workshops where the peer-review evaluation tool was applied on participants' instructional materials on biorisk management.[513] Results are positive, possibly not surprisingly with higher averages for simpler learning objectives related to the Analysis and Design components. Bigger challenges may be related to addressing different types of learners and communication

[513] I remind that the items and criteria included in the peer-review tools are selected by participants and hence are (to some degree) different every time. See Chapter 7 on the reasons for the peer-review as a training activity itself.

modes, something that may be related to a higher level of learning but also to the practicality of the exercise being limited to a short and focused activity.

Table 42 - Results of peer-review assessments on developed and implemented instructional materials

Indicator	Question	Country C[514]	Region A[515]
Knowledge: Understand: what to look at to characterize learners and instructional context	The audience was well defined	4,5	-
	The training was relevant to the audience for which it was designed	4,4	-
Knowledge: Apply: draft learning objectives	Did the activity meet your expectations?	-	4,4
	Was the activity relevant to the lesson's objectives?	-	4,5
	The training contributes to the larger objective for societal benefit (biorisk mitigation)	4,5	-
Skill: Apply/Analyse: use learner-centred education development and implementation methods	How adequate was the organization of the activity?	-	4,3
	How clear was the message?	-	4,3
	How effectively was interaction used?	-	4,4
	Did the methods utilized help you understand the topic?	-	4,3
	Was the activity enjoyable?	-	4,3
	Was the activity memorable?	-	4,3
	How adequate was the organization of the activity?	-	4,3
	Was the activity designed to overcome communication barriers?	-	4,1
	How effective was the communication mode?		4,2
	Did the training address different types of learners (theorist, reflector, pragmatist, activist)?	4,1[516]	4,1
	The training uses recaps and summaries	3,9	-
	The training uses principles of learning (e.g. primacy, recency, exercise…)	4,0	-
	The learning objective is better achieved with facilitated learning techniques	4,2	-
	The training has a compelling relevance to real life situations	4,3	-
	The training meets the learning objective	4,6	-
	The principles and practices of the training are appropriate	4,3	-

Finally a useful data source for measuring indicators of instructional capacities among professors are the interviews where I asked educators about their instructional practices or how they felt about effectiveness of educational design and delivery methods. In this sense, the conversation with Professor 9 provided a number of interesting empirical confirmations of the value of instructional design pillars, especially the learner-centred-delivery one. In the interview for example, they made suggestions that clearly connect with principles discussed in Chapter 7, and that would suggest grasp of learning objectives on the Development and Implementation components of the ADDIE model. Here they reflect on something similar to what we referred to as "surprise", and that the dual-use issue has a stronger catch on students if it is presented as a dilemma

[514] Average peer-review score from three groups.

[515] Average peer-review score from five groups.

[516] "The training addresses different types of learning styles giving freedoms to the learners."

emerging from a scientific case, rather than as a specific problem addressed separately:

> *Professor 9: "to have the student actually <u>interiorizing</u> it, it's not enough to give him a list […] … an emotional shock, I don't know how to call it, I mean the fact that the student has to see himself in the condition… so if I tell you this example, this or that, and I give you some kind of a general overview…er… in my opinion it strikes the student much less, or… it <u>doesn't link</u> it to what he is studying specifically, while… if I introduce it for some aspects in the virology course, for another aspect in a course, let's say, of pharmacology, or simply in that of cellular biology or of <u>immunology</u>, that I think it's the more relevant one, because actually the problem is that I move it on what its effect is… and so, I can much more strongly link it to all the other stuff that we covered and that didn't have anything to do with that problem, but I move, if I just move <u>a little bit</u>, and there I fall in it, which is different to say 'now… a completely independent course will tell you about that problem'… I mean, at least I see it… this way […] I can <u>lead</u> the student almost to introduce him to an activity that does not… and so it starts, in a very <u>featureless</u> way… that has inside… but then instead of concluding with scientific information, actually it opens up this discussion. And one got there almost without even realizing it.*
>
> *GMM: realizing it, yes*
>
> *Professor 9: which by the way is much closer… to what actually happens in reality."*[517]

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[517] Translated from the original Italian: *Professor 9: "perché lo studente in realtà lo faccia <u>proprio</u> non basta fargli un elenco […]… uno shock emozionale non so come dire, cioè il fatto che lo studente deve vedersi, lui, nella condizione… allora se io ti racconto questo esempio, questo o quell'altro, e ti faccio una specie di panoramica generale… er… secondo me colpisce molto di meno lo studente, oppure… lo <u>svincola</u> da quello che sta studiando in modo più stretto, mentre… se io lo metto per alcuni aspetti nel corso di virologia, per altro in un corso che sia di farmacologia, oppure quello di biologia cellulare semplicemente o di <u>immunologia</u>, che per me è la cosa più vicina, perché in realtà il problema è che lo sposto su quello che è l'effetto… e quindi, riesco molto di più a collegarlo a tutte le altre cose che abbiamo visto tranquillamente che con quel problema non avevano niente a che vedere ma mi sposto, basta che mi sposto un <u>pochino</u> e in realtà ci casco dentro, che è diverso rispetto a dire 'adesso… un corso completamente indipendente va a parlarti di quel problema lì'… cioè almeno io lo vivo…così […] Posso <u>portare</u> lo studente quasi quasi a proporgli una attività che non… e quindi parte, in modo molto <u>anonimo</u>… presenta all'interno… ma invece*

While here on utilizing and tailoring media resources:

> *Professor 9: "…what I would like to find is some discussion or presentation on YouTube because… I mean, YouTube, Vimeo or whatever… accessible… as I found a system to make it interactive, so I can add text and make it more integrated with the lecture, it's not just 'go watch this on YouTube', and to have students answer to quiz questions, and… so I mean if there's something that you can suggest me that can be useful, that would be a very useful tool."*[518]

And here proposing ideas to achieve and test higher levels of learning objectives for students, demonstrating understanding of how Development of instructional materials needs to be consequential to Design (e.g. "analyse" or "evaluate" learning objectives are hard to teach or evaluate with simple tests):

> *Professor 9: "like, for example, an activity, an exercise could be… there again… it would be necessary to prepare some material but, could be to put the student in role of being a commission deciding on some funding, or whatever could be the situation…*
>
> *GMM: and maybe evaluate that too, because it could somehow be the development… it would introduce this learning objective of a higher… level…*
>
> *Professor 9: yes […] I mean, we would need an exercise book on this thing… I mean what could be presented as… fictional case studies…"*[519]

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di concludersi con un dato scientifico, in realtà apre a questa discussione. E uno ci è arrivato quasi quasi senza rendersene conto.

GMM: rendersene conto, sì

Professor 9: che poi è molto più… vicino a quello che ti succede nella realtà."

518 Translated from the original Italian: *Professor 9: "… la cosa che mi piacerebbe trovare è qualche discussione o presentazione di qualcosa messo su Youtube perché… dico Youtube o Vimeo o altro sistema… accessibile… più che altro perché ho trovato un sistema per poter renderlo interattivo, e quindi per poterlo aggiungere del testo e quindi farlo parte più integrante della lezione, non soltanto vai a vederti questa cosa su Youtube, e di poter sia far rispondere a delle domande a quiz, sia… cioè e quindi questo se c'è qualcosa che mi segnali che possa essere utile questo sarebbe uno strumento molto utile."*

519 Translated from the original Italian: *Professor 9: "come ad esempio una attività, un esercizio che potrebbe essere, anche lì… bisogna preparare un po' di materiale, è mettere lo studente nella posizione di essere una commissione che decide per dei fondi, o quella che è la situazione…*

9.3 Level 3 - Behaviour

The third level of Evaluation, behaviour, looks at if the principles of instructional design for education on managing specifically deliberate disease risks and other biorisks have been transferred by educators in the practice in HEIs and sustained over time. As discussed in Chapter 7, this is related to the Implementation component in the ADDIE model. Indeed a sustainable implementation of education on biorisk management and to mitigate deliberate disease risks is one that is imparted by local educational systems and instructors, rather than what was tested by external instructors as me and others (the latter being courses and programs whose results have been presented in the previous Chapter on Evaluation in the education plan). This implementation is what is evaluated in Levels 3 and 4 of evaluation in the instructional design plan. Level 3 looks at implementation centred on individual professors, assessing if after being engaged in projects to promote education to mitigate deliberate disease risks, and in some cases completing ISD workshops, they go and implement something in the instruction to their students. The designed indicator proposed in Chapter 6 is indeed that participants teach to their students.

Some of the experiences from the projects that were analysed during interviews suggest that they reached this level of impact, as some professors actually went back to their teaching practice and HEIs and introduced some teaching to their students; promoted educational initiatives; and/or transferred the designed and developed instructional materials to their courses. So for example Professor 9 has, as already mentioned, introduced a lecture on dual-use in their introductory course on cellular biology for Master students of life sciences degrees, using instructional material developed in the framework of the project they participated in; as well as included a question on the topic in the final test:

> *Professor 9: "[…] I have to say that for what regards me, in the Master degree course of cellular and molecular biology, and I have all… I have the students from all specializations, so I have them all, I always kept in*

GMM: e magari fare una valutazione anche su questo, perché sarebbe anche un po' il passaggio… inserirebbe questo obiettivo formativo un po' più… er… elevato…

Professor 9: sì […] cioè ci vorrebbe un libro di esercizi su questa cosa… cioè è quello che si presenta come… dei casi finti…"

my course, including… er… one lecture on this type of topic, and… making students reflect on it.

GMM: so on… on biosecurity… because biosafety is already there…

Professor 9: actually on dual-use. […] yes, I continued to do it because what… is easier to present is the story of mice in Australia. Because actually for us it's… for this type of education, being it a genetic manipulation… and with me covering sections that are really inspired by these opportunities… to modify the genome, to introduce new sequences, to improve, to make transgenic animals, to be able to do all that, it's <u>really</u> close…

GMM: to what…

Professor 9: … then again, my colleague covering virology, covering… they could probably do it better than I can… however… I always thought it would have been important to keep it… so I… I kept it.

GMM: yes, yes. Using the…

Professor 9: using the [instructional] material that was collected, initially, in some of the initiative that we did… […] obviously I can't always put the same question [in the test] or it becomes too easy, but I regularly included an open question specifically on dual-use or on reprising some of the examples we had seen in class so that they could comment it."[520]

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[520] Translated from the original Italian: *Professor 9: "[…] io devo dire personalmente nella laurea magistrale di biologia cellulare e molecolare, e ho tutti i… ho gli studenti di <u>tutti</u> gli indirizzi, e quindi li ho totalmente, io ho sempre continuato nel mio corso, a mantenere…er… una lezione su questo tipo di argomento, e… e a far riflettere gli studenti su questo.*

GMM: quindi su… sulla biosecurity… perché biosafety è già…

Professor 9: proprio sul dual-use. […] sì, ho continuato a fare perché è la cosa che si presta… più facilmente è la storia dei topi in Australia. Perché in realtà per noi è… per questo tipo di formazione essendo una manipolazione genetica… e facendo io tutta una parte che prende proprio spunto da queste possibilità… di <u>modificare</u> il genoma, di poter introdurre nuove sequenze, di poter potenziare, di poter fare gli animali transgenici, di poter fare tutta questa cosa, è <u>molto</u> vicino…

GMM: a quello che…

Professor 9: …poi, ripeto, il collega che fa virologia, che fa… potrebbe farlo probabilmente meglio di quanto lo posso fare io… però… ho sempre ritenuto fosse importante mantenere… perciò io l'ho… l'ho… mantenuto.

GMM: sì, sì. Usando il…

Other instances of implementation by individual professors engaged in projects have also been claimed by Professor 3 (who teaches biotechnology students); Professor 4 (who teaches engineers), Professor 5 (who teaches life sciences students); and Professor 7 (who teaches medical students).

> *GMM: "have you seen something changing in how the topics were incorporated… or…*
>
> *Professor 3: yeah. People are reporting about it. It was really… I sometimes feel that I am lucky. I am involved in this, because of me, people consider in [this country] me as pioneer now, wherever there is a meeting, there is a special session on conduct of responsible science, and they usually invite me…"*

> *Professor 4: "yes, so, embarrassingly enough… it's only, you know… mainly our own contribution through me and other teachers in biology, we had some initiatives by the engineering program who introduced an ethical course for engineers, but it's more directed towards product development, sustainability, what kind of responsibility you have to your customers, to your company, to society, so it's not really a bio…er… direction, although it does talk about the responsibility you have as a researcher…*
>
> *GMM: and in engineer[ing] respect*
>
> *Professor 4: engineer, but not really the bio… er… direction of it, so they do not talk about biosafety and biosecurity, so the things that the students have today, the subjects and the modules that… through myself and our professors in biology, has happened. So I saw it as a sort of big responsibility now that we have more formalized it and the way we have done with the first initiatives that we had seminars, we had lectures, on biosecurity and biosafety for engineers, er, and also for our biology*

Professor 9: usando il materiale che era stato, poi alla fine… inizialmente… raccolto in alcune delle iniziative che avevamo… […] Ovviamente non posso sempre mettere la stessa domanda, se no diventa troppo telefonata, ma in modo ricorrente fatto una domanda aperta e quindi dove su in particolare il dual-use o oppure su il fatto di riprendere alcuni degli esempi che avevamo visto a lezione che loro potessero commentarlo."

students through me or other teachers or through the centre for bioethics […]"

Professor 7: "yes, open… so I told them, this is from security wise… safety… should address… er, shoe <u>cover</u>. Er, we showed them also a video on the entrance of the lab without authorized… this is <u>security</u>. So, this start now, we start to… to teach students that not anybody is allowed to enter the lab. Not because of infection or contamination, but for… <u>bad intention</u>."

While Professor 6 was not yet able to implement education but does plan on introducing something:

GMM: "Er, have you seen, you know, since the new academic year has started, have you seen or do you, er, <u>anticipate</u> any change in the educational offering in this direction, do you see these topics, biosafety and biosecurity, biorisk management more in general, being inserted in the curricula, in the future?

Professor 6: why not, because this is very very important. This is very important and should be, and some part is already as I told you, it is already there and since I am now having more of awareness and access to… er… the things, I would want it to be <u>strengthened</u>, because I don't say that they are not <u>there</u>, they are already introduced, but strengthening is required, which I can do after, you know, attending the workshop. So… definitely, I see future, in future that these things should be incorporated if they are not there, but in <u>our</u> curriculum it is there, and you know, after doing this workshop I saw to it that it is… you know… incorporated into the pre-PhD program. I will do that."

Data for Level 3 evaluation are also available from content analysis of publicly available secondary data. Professors at the University of Granada in Spain and the Quaid-i-Azam University in Pakistan, for example, who were involved in the EUBARNet and Pakistan projects, independently continued to organize awareness raising seminars on dual-use and broader biosecurity issues also after the specific projects ended up to 2016 (Tanveer and Shinwari, 2015a; Universidad de Granada, 2016).

Notwithstanding the above reports from many of the interviewed professors that they started implementation of education on biorisk/deliberate disease risks management to students following up to our engagement and training projects, these experiences are not generalized for example to all participants to train-the-trainer programmes as many faculty members did or could not follow up as much. Challenges could on the one hand be due to training problems (those that the ISD train-the-trainer programmes would aim at solving), and on the other hand to non-training problems of external limitations such as a rigid curriculum system in HEIs. The interviews with professors provided some insights on these types of challenges that educators could face introducing new instruction. Professor 4 for example illustrates well what could be training problems in faculty that may hamper Level 3 impacts:

> *Professor 4: "I think what we are missing is a discussion among the teachers, how are the areas been changing and what possibilities does it bring that we can order things from companies, and so on. We <u>have</u> tried to have teachers' meetings, and especially now when we have these ethical modules on courses, we have to include the teachers, because we say 'we can't bring in the experts all the time, <u>you</u> have to talk about this'. And some teachers say 'ok, I will not do it', but we do have a growing group of teachers that also like working with the students, because… you were talking about teaching methods, and we actually tell the teachers 'you cannot lecture only, you have to do other things', because if you don't introduce or have the students themselves talk, you know, <u>do</u> things, we cannot prove that they actually <u>gain</u> awareness, during this process. So some of the teachers… er… opposed to, you know, that we said, 'lecture is not enough', yes so the methodology, the…. 'Oh, my gosh, cant I do my lecture'… and we said 'no, you have to do it in a different way', but some teachers… really like that, so we try to work from those teachers. So I think we <u>are</u> growing also in awareness with the teachers, that we have to talk to the students and we have to bring in the new technologies also, with a risk assessment."*

On the other hand, Professor 2 notes that in their national higher education systems professors don't have a lot of autonomy to change courses[521], and hence they could introduce the subject but had to opt for extra-curricular seminars rather than having it structured into courses:

*Professor 2: "[…] at the level of universities *******, professors cannot change courses as they please…*

GMM: directly

Professor 2: …directly. And [courses] must be accredited by the Ministry of Higher Education

GMM: the government

*Professor 2: … by the government, by the Ministry of Education, and notably by a national commission called the *****, the Accreditation National Commission. And so, our colleagues, after our action, what they introduced are rather some <u>seminars</u>."*[522]

Which is similar to what Professor 4 reports, but with their opinion on the weaker learning effect such format can have on students:

Professor 4: "[…] I think in that sense we have targeted a lot of the students, but when we measure it, we ask the students what have you done in this, and they say 'oh, we had the seminar', they don't remember it."

---

[521] While in most other cases interviewed professors reported revision processes for courses in which professors of local departments have some degrees of autonomy from a central approval agency. See for example this description from Professor 6 that is a good example: *"yes, there is a committee which is known as the board of control. So, the curricula that… whatever curricula that we make, it goes to… into that… for meeting into that committee, and then people decide. And then it goes from approval, then it goes to the higher authority, where there is a science research board which gives a, a larger body, which gives it approval, finally, for… a particular course to run in the department".*

[522] Translated from the original French: *Professor 2: "[…] au niveau des universités ******, les professeurs n'ont pas le droit de changer des cursus comme ça…*

GMM: directement

Professor 2: …directement. Et il faut que ils sont accrédités par le Ministère de l'Enseignement Supérieur

GMM: l'Etat

*Professor 2: …par l'Etat, par le Ministère de l'Enseignement, et notamment par une commission nationale qui s'appelle la ****, la Commission Nationale d'Accréditation. Et donc, comme fait les collègues, suite à notre action, ce que ils ont introduit des <u>séminaires</u>."*

Indeed this comment by Professor 4 suggests that even when some Level 3 result was possible (and even more so when it was difficult), a formalized introduction in the educational system is more desirable for sustainable, generalized implementation, that is, more effective education. While results on Level 3 are important, stopping there is not just less effective from the learning point of view, but also leaves instruction dependant on the initiative of the individual, and hence not sustainable, as Professor 5 notes:

GMM: "so this course is taught to various students, in various degrees, and has a… a small part that also considers these subjects

Professor 5: now it has. So, for instance next year, next January I am not in charge of this discipline anymore

GMM: so, you wont be there… you don't think it will stay

Professor 5: I don't know, I have to talk with my colleague, if she… for instance if she wants me to give a talk

GMM: so you don't think that it is something that right now is sustainable enough… because it depends from you

Professor 5: no, we have to… of course we have to present to the scientific committee to…

GMM: to make it…

Professor 5: to make the change"

9.4 Level 4 - Result

The limitations of the achievements measured by Level 3 indicators considered above explain why it is important to look at formalized implementation in educational programs, what we have designed as Level 4 results in the instructional design plan. If education is analysed as a necessary (yet, as observed, not sufficient) component of technical formation to mitigate risks of deliberate disease, it should be explicitly included in learning objectives and built into the formal course designs of HEIs. The indicator for evaluating Level 4 results proposed in Chapter 6 was the "formal introduction in instruction programs (new or revised credited instruction)".

In the projects considered by this research, such result was achieved in a number of cases in connection with the collaborative work with professors and decision-makers in HEIs, which in some cases included the ISD train-the-trainer programmes. In one of the HEIs involved in a project, while the university had already decided the inclusion of a course on biorisk management in the syllabus of one of their Master courses before designing and developing it, awareness raising of educators and ISD train-the-trainer was instrumental in creating effective instructional materials:

> *GMM: "[…] did you see a change in the course degree?*
>
> *Professor 8: definitely*
>
> *GMM: in the syllabus*
>
> *Professor 8: definitely*
>
> *GMM: because you have a course, right, a new course… and… so you have seen a change*
>
> *Professor 8: I think, that time when we did the course review…"*

Country A University 1 and Country A University 2's faculty members planned to move in a similar direction of creating a "cross-cutting" course covering biosafety and biosecurity for all undergraduate students of life science and technology degrees before they specialize in the various subject matters.

Partly as a result of engagements over the years, Quaid-i-Azam University in Pakistan introduced a core 3-credit hours course in Bioethics & Dual-Use Education for Masters in Biotechnology students as well as an optional 3-credit hours course in Biosafety & Biosecurity (QAU, 2014; Tanveer and Shinwari, 2015a). At least one of the professors engaged in the Region A ISD workshop was tasked by their leadership at the home HEIs to redesign an existing course on Good Laboratory Practice and Quality for Master students of Immunology to expand and introduce biosafety and biosecurity teaching.

Some of the interviewed professors who firstly achieved "individual" results that have been discussed under Level 3, then reported on Level 4 outcomes as well. Professor 2 reported in their interview that, also based on the experiences gained in the collaborative projects on promoting education with me and other colleagues, they established a Master degree in biosafety and biosecurity:

Professor 2: "[…] finally we created, starting in September, a Master, the Master in biosafety and biosecurity, and that's a first at the national level… and even I would say at the international level, because this is a degree recognized by the government, that is going to train trainers, people who are going to be experts, and who will then work."[523]

However, interviewed educators seem clear that the primary goal would be to formally introduce the subjects into new or existing courses of a large range of life sciences and health degrees, rather than aiming at forming specialists on managing biorisks. So the same Professor 2, following up from the mentions of challenges in Level 3 for "informal" introduction in seminars presented in the previous paragraph, that

Professor 2: "[…] so this… […] it used to be a problem, but starting this year we had a, how to say, reform of higher education system at the level of universities and there colleagues introduced some teaching modules.

GMM: ok.

*Professor 2: so, these modules, which are now accredited by the government and hence it's something very important. Now, and I would say not all universities, but a good part of the ******* universities, within courses, within their curricula, some modules on biosafety, biosecurity, and dual-use. And this is something very important, it's… and this is going to continue, will continue."*[524]

[523] Translated from the original French: *Professor 2: "[…] dernièrement nous avons créé, a partir de Septembre là, un Master, le Master de biosécurité et biosûreté, et c'est une première au niveau national… et même je dirait au niveau international, parce que c'est un diplôme reconnue par l'état, qui vais former des formateur, des gents qui vont être des experts, et qui vont travailler plus tard. "*

[524] Translated from the original French: *Professor 2 : "[…] Donc, ça… […] était un problème, mais là a partir de cette année on a eu toute une, comment dire, reforme de l'enseignement LMD au niveau des universités et là les collègue ont introduit des modules d'enseignement.*

GMM: ok.

Professor 2: alors, des modules, qui sont accrédités maintenant par l'Etat et donc c'est quelque chose de très important. Maintenant, et je dirais pas toutes les universités, mais une bonne parte des universités

Furthermore, Professor 4 describes the reasons and the ways of their move from a "Level 3*" to a "Level 4*" implementation, as well as the extent of the latter:

> *Professor 4: "So what we have moved on to right now is to make it more visible, so we have introduced it into every program… that we have…so what we are moving on to, like the last two years we worked on having, so ***** prepared, she went through all our curricula for biology, er, Bachelor, Master and engineer program which has bio direction, and she went through that and made suggestion for including in all the curricula that we are responsible for, er…. Parts of ethical, you know, character, so it includes biosafety, biosecurity, dual-use, but also… er…publication ethics…*
>
> *GMM: […] has not… has still not been incorporated in the normal curriculum or…*
>
> *Professor 4: oh, it is, absolutely*
>
> *GMM: ah ok*
>
> *Professor 4: ok, so for every course, like the introductory course that I teach, we have one <u>goal</u> for that course that concerns bioethics, so that was one part of making it more visible, so even if I am not the teacher anymore, this is the goal for the course, which means that whoever teaches this course, has to write or, you know, be aware of this goal, and also show what the <u>content</u> to reach this goal, and also how to <u>assess</u> that the students really have done this, so they have to show in different ways you know, depending on if we have a seminar, they have to participate in that seminar."*

While Professor 7 had a course formally introduced covering biorisk management and bioethics within the syllabus of a Bachelor of medical laboratory sciences:

> *GMM: "so, er… do I understand correctly that in the course you have <u>now</u>, you do not teach biosecurity, to students?*

*********, *<u>en seine</u> des courses, dans leurs cursus, des modules de biosécurité, de biosûreté, et double usage. Et ça c'est quelque chose de très importante, c'est un… et ça va continuer, ça va continuer."*

Professor 7: no, we teach, but…

GMM: some of that

Professor 7: yes, but, but our focus was on biosafety.

GMM: mmh. I see

Professor 7: but for this reason, we called the course biorisk, we didn't call it biosafety. Because… we are planning to include both. Biosafety, biosecurity. We didn't call it biosafety only. We called it biorisk. And we agreed before that, when we say biorisk we mean two. Biosafety, biosecurity."

Other professors who had not witnessed results that could be ascribed to metrics for our Level 4 indicator, indeed reported some ideas and plans for future formal implementation, such as Professor 1 and Professor 4:

Professor 1: "[…] all students who enrol in a PhD are obliged at the end the three years, they cannot defend their thesis, and documented to have followed two hundreds hours of training. There are two hundreds hours of training, they are not fixed, there is no defined programme. We could have sixty hours on science, forty on pedagogical approaches, or on pedagogical innovation, and [unclear] thirty or forty hours of courses on bioethics, on… property rights, law, the problem of plagiarism, the problem of…

GMM: intellectual property

Professor 1: exactly. And the problem for all those who will attend, who will attend PhDs in exact or natural sciences, all that is in relation with biosafety and biosecurity. And the problem of raising awareness regarding the issue of possible dual-use. Because not everybody is aware."[525]

[525] Translated from the original French: *Professor 1: "[…] tous les étudiants qui s'inscrivent au Doctorat ils sont obligés au bout de trois ans, ils ne peuvent pas soutenir leur thèse, et justifiés pas d'avoir suivi deux-cents heures de formation. Ils sont deux-cents heures de formation, elles ne sont pas fixées, il n'y a pas un programme définitif. On peut mettre soixante heures de scientifique, quarante heures d'approche*

*Professor 4: "I have to check when I get back home, but what I told our… our Dean for the natural sciences and technology is that, 'ok we're sort of leading it in biology because, you know, these questions are just, you know so important to us, but what we do can be used for the other educational programmes', so that's what happened this fall, that we got funds to coordinate <u>all</u> the educational programmes in natural sciences and technology in ***** [university], and that's a bit overwhelming, so I said you know, we gonna use our project in biology and do some of the modules for other educational programmes."*

An interesting theme regards the opinions on effective drivers for Level 4 achievements according to the interviewed professors. Responsibility for course design may be with central national coordination bodies, which should be engaged to facilitate a generalized introduction. Depending on national education systems, these bodies could be governmental, as those mentioned by Professor 2 in the quotes in the Level 3 discussion, or academic as in the experience reported by Professor 9:

Professor 9: "as far as I know, that topic… at the national level, it didn't catch, and we didn't have the time to consolidate it because we got out […] from the [national academic coordination committee] […]

GMM: so that could have been a… a strategy or a… to generalize it…

Professor 9: yes, because they continued working on other topics…

GMM: that had been…

Professor 9: … I still know people active there whom I could contact back, one in particular… er… works with me on a working group of the

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pédagogique, ou d'innovation pédagogique, et vont [unclear] trente ou quarante heures des cours sur la bioéthique, sur… le respect de la propriété, du droit, le problème du plagiaire, le problème de…

GMM: intellectual property

Professor 1: exactly. Et le problème pur tous qui vont suivre des, qui vont faire des Doctorat en sciences exactes ou sciences naturelles, tous qui est en relation avec la biosécurité, la bio sûreté. Et la problématique du sensibiliser au problème qui peut avoir de double usage. Parce-que tout le monde l'est pas consciente."

[national evaluation agency for HEIs] and so we are in very close contact, actually I could even raise the topic with them…

GMM: so but, why do you think, in that case, in the [national academic coordination committee], it didn't continue, it didn't catch?

Professor 9: I think because nobody took the responsibility [being '<u>the advocate</u>'] of the issue."[526]

The above quote at the same time strongly underlines the need for individual action (promotion, advocating) to be sustained within the national coordination bodies. Other drivers quoted by interviewed professors point to international collaborations to raise the interest especially on deliberate disease risks, as Professor 9 below, and audits on instructional systems by national coordination bodies on HEIs, as Professor 4 relates:

Professor 9: "in my opinion the most interesting thing was the interaction at the <u>international</u> level, I mean from my point of view I noticed the biggest progress when that topic was brought into this project <u>[project name]</u> […] The biosecurity aspect, in my view is <u>much</u> more bound to teaching strictly speaking, because I have to stimulate a reflection, I have to <u>shape</u>, it would fall we could say… er… more in the Dublin descriptors…"[527]

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[526] Translated from the original Italian: *Professor 9: "a mia conoscenza quel tema lì… a livello nazionale, non è riuscito a sfondare, e noi non abbiamo avuto il tempo di consolidarlo perché siamo uscite […] dal... [comitato accademico di coordinamento nazionale] […]*

GMM: quindi quello avrebbe potuto essere una… una strategia o una… per generalizzarlo

Professor 9: sì, perché hanno continuato a lavorare su altri temi…

GMM: che erano stati…

Professor 9: … conosco ancora gente attiva sui quali potrei riprendere anche alcuni contatti, perché una in particolare… er… lavora assieme a me in un gruppo di lavoro dell'[national evaluation agency for HEIs] e quindi sono in contatto molto stretto, in effetti potrei anche sollevare il problema con lei…

GMM: ma, quindi, perché, secondo lei in quel caso, nel [comitato accademico di coordinamento nazionale], non ha continuato, non ha fatto presa?

Professor 9: secondo me non c'è nessuno che si è fatto <u>portavoce</u> del problema."

[527] Translated from the original Italian: *Professor 9: "per me la cosa interessante è stata il confronto a livello <u>internazionale</u>, cioè dal mio punto di vista il salto più importante l'ho visto quando quella tematica è stata portata all'interno di questo progetto <u>******</u> […] L'aspetto di biosecurity, a mio avviso è <u>molto</u> più legato alla didattica nel senso stretto, perché devo aprire una riflessione, devo <u>formare</u>, rientra potremmo dire….er… più nei descrittori di Dublino…"*

*Professor 4: "[…] This is something we have also worked on, to make it more visible, because we had from our education ministry, they had an audit of all our education, and one of the things that they actually failed us on, we had really good grades, and actually they could have failed us saying you know, 'you do not reach the goals set by the ****** education system'…*

GMM: which includes…

Professor 4: …which includes ethics. And actually it was something that it was noted for all… I think almost all universities in [country] that, the goal for to reach that the students are aware of the ethical, you know, considerations, has not been fulfilled with any university, so we went back to ourselves and said ok, next time when they come, how do we prove that, because the students will say 'oh, I did have a seminar, cant remember' and so on, so we would have to show them proof, that from my course, we had these and those contents that, you know, were raised against these things, we had the goal, we had the assessment, so I have to show them exactly in detail which were the questions for the exam for that goal…"

9.5 Conclusions

Evaluation of reaction of educators to ISD train-the-trainer workshops and collaborative programmes on promoting education for students as a tool to mitigate deliberate disease risks (and other biorisks) suggests that Level 1 objectives were achieved by such efforts. Metrics for the indicator that participants were "satisfied, interested and engaged" include that strong majorities of participants were satisfied with the training events and thought that the train-the-trainer programmes were important and relevant to their position; positive comments on post-ISD workshops questionnaires; and continued participation of educators to collaborative projects on education over the years. Empirical data regarding learning objectives/Level 2 indicators suggest that designed learning objectives were achieved on key capacities on the Analysis, Design, Development, Implementation and Evaluation components of the instructional design model, though at different degrees. Indicators were measured using results from self-assessment surveys, instructional design documents and materials produced by participants, who in many cases felt and demonstrated to understand instructional analysis, to be able to draft learning objectives and design education, and to use learner-centred-delivery methods. I also presented empirical data to support that actions in considered projects supported the achievement of Level 3 indicators with the initiation of locally driven educational activity. These included several examples of professors introducing lectures and seminars for their students on biorisk management and deliberate disease risks. Identified challenges for achieving Level 3 objectives include both possible training problems (such as the need to train the educational staff) and non-training problems such as rigidity on the curricula contents.

I have reiterated however the considerations from Chapter 6 on educational Design that achievements limited to Level 3 would not assure an effective impact on the instruction design plan, a view confirmed by interviewed professors. The indicator for Level 4 results indeed looks at if instruction has been formally introduced in educational programs in higher education systems, something that makes education to mitigate deliberate disease risks a recognized (or even required) component of technical instruction and doesn't leave it dependent only on initiatives of individuals. Empirical data I presented suggest that such level of result was achieved in a number of situations supported by considered projects, including examples of courses or modules introduced or revised to include capacities on biosafety, biosecurity, and/or related risk management, as well as similar plans for the future. Interviewed professors mentioned a combination of "bottom-up" and "top-down" facilitating factors for formal introduction of education to mitigate deliberate disease risks, based on their experience. The former would include efforts by interested individual educators who take leading roles in promoting the idea onto decision-makers and raise the awareness of other faculty members; the latter would include the work through central coordination bodies of curriculum design for higher education at the governmental or academic level. The engagement of educators to raise the awareness on education to mitigate the risks of deliberate disease, and their training on ISD to implement it, seems important especially for the "bottom-up" mechanism as in some way it would improve the likelihood that educators move from Level 2 on the instruction design plan to Level 3 and finally contribute with their actions to Level 4 results.

At this point it should be noted how Evaluation in the instruction design plan of research does not only mean assessment of reaction, learning, behaviour and results on instructional design, but also includes the follow-up feedback to review, revise and if necessary improve initiatives on the instructional design plan. Considerations I would advance for example regarding the Analysis and Design of train-the-trainer programmes, based on achievements and challenges from past experiences, include to make sure that participants have at least a basic grasp of the thematic area they should then design instruction on. This would include achievement by participants of some “know” and “understand” learning objectives in the education plan before moving them to the instruction design plan. Furthermore, selection of participants (which too relates to sound Analysis and Design decisions when preparing train-the-trainers programmes) to collaborative and train-the-trainer projects is key to improve chances of achievements on Levels two, three and four. Participants who have stronger roles on lecturing, for example, would be more likely to achieve Level 3 indicators (provided there are not other non-training problems in their context), however if they have no course design, review and approval responsibilities they may not be able to influence Level 4 results. In this view, the engagement of participants with decision-making responsibilities such as Deans, course coordinators, and members of national curriculum coordination committees (in addition to, rather than instead of, participants with largely lecturing responsibilities) has proved effective to achieve Level 3 and especially Level 4 objectives quicker and to a wider extent. Thirdly, these experiences suggest to more strongly include methods and techniques of instructional design and development in the instruction design plan, such as making sure to “prepare” participants, for example with the use of pre-workshop readings.

Finally, while it would be difficult to irrefutably demonstrate that Level 4 results were a consequence of the engagement projects and/or the train-the-trainer programmes on education to mitigate deliberate disease risks, certainly the conversations with professors who were involved in promoting education to their students suggest their actions were at least initiated by the work in those projects. Consider for example these quotes from Professor 2, Professor 5, Professor 9 and Professor 4:

Professor 2: "there are many experiences that have been collected, notably, so, thanks to the cooperation with the Landau-Volta centre. And so, in that framework, we had looked after a first situational analysis, of knowledge in the field, I… I understood biosafety, biosecurity and dual-use, after this situational analysis, we realized that it was important to… er… going deeper into education at the university level, and into education of, of… not just awareness raising… education at the level of universities".[528]

Professor 5: "my first contact with this, kind of topic, was during [project name] when… you… there was the conference, not the conference, it was like...

GMM: like a seminar

Professor 5: a seminar, or something. And…

GMM: in [your university]?

Professor 5: in [my university]. So… I had never thought about this, I didn't have content, and in the, the curriculum, in biology, […] we don't really think about this. So after [project name] and filling the questionnaire… 'oh my god, I am not… I don't know what this means! I really need to learn a little bit more.'"

GMM: "but… er… so… also following or as a result or in relation to the activities carried also in those projects […] did educational offerings change, that included this topic? One I think may be the example of [project name], which had…

Professor 9: which integrated it

[528] Translated from the original French: *Professor 2: "il y a beaucoup d'expériences qui ont été accumulées, notablement, donc, grâce à la coopération avec le centre Landau-Volta. Et, donc, dans ce cadre là, nous avons vu après un premier état de lieu, de connaissance dans le domaine, je… j'entendait biosécurité, biosûreté et double usage, après ce état de lieu, nous avons vu qu'il était important de…er…d'aller très profondément dans l'éducation au niveau universitaire, et l'éducation de, de… n'est pas uniquement la sensibilisation… l'éducation au niveau des universités."*

GMM: … It integrated it, also… er… in relation to your proposals, your opinions that also derived from…

Professor 9: … from the previous experience… yes."[529]

*Professor 4: "Of course the terminology and the works and the projects was all new terminology and a new kind of people to meet, but I've seen it since we started like a constant… contribution to my work in [university] because it taught me where to find material, and where to find people, that I could connect to, to make the content of our curriculum in [university] more professional…. er… more specifically to questions… […] so I am really glad because this… these projects, I should say, have been a lot of inspiration and a lot of gain in knowledge for me to work with that in ****, and for our very much on the ground level with our students in our daily activities, so that has been good."*

I think it's hence possible to conclude that the examples of projects considered in this research to engage the life sciences/public health higher education community and to train educators on instructional systems design, include tools that could support an effective design and evaluation of education of students on biorisks and deliberate disease risks as a tool to mitigate the latter.

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[529] Translated from the original Italian: *GMM: "ma… er… quindi… anche in seguito o in conseguenza o in relazione alle attività fatte anche in quei progetti […] sono cambiate delle offerte formative che hanno incluso questo? Uno credo sia l'esempio di [progetto], che ha avuto…*

Professor 9: che l'ha integrato

GMM:… l'ha integrato, anche… er… appunto in relazione alle sue proposte, alle sue opinioni che derivavano anche da…

Professor 9: … dall'esperienza pregressa… sì."

10. Conclusions

The objectives of this thesis were to examine how education was constructed as a potential security tool to mitigate the security risks of deliberate disease, discuss if and how education could influence deliberate disease risks, and propose options and tools for effective education to mitigate deliberate disease risks. With "effective", I meant education that can be relevant, generalized and sustained. How the thesis pursued these objectives was through firstly applying securitization categories to analyse the role of education in security; secondly using a research framework to connect outcomes in terms of education to outcomes in terms of risks; and thirdly leveraging empirical data (including both original and pre-existing primary data, as well as secondary data) to develop and illustrate possible design and evaluation tools for education as a risk mitigation measure.

10.1 Overview of findings and activities of the thesis

The thesis defined the research framework in Chapters 1 and 2. The former presented the research situation, its opportunities and criticalities, methodological and data generation and management aspects. The latter explained the theoretical framework, which critically combined components of securitization, discourse analysis, risk assessment, science of education, and the web of prevention. Three main conceptual areas and categories interplayed: security, risk, and education, all within a (weak) social constructionist approach. Securitization has been used to analyse attempts to advance education of scientists as a tool to mitigate the risks of deliberate disease. Risk assessment has been used to identify and characterize risk scenarios and understand if education may impact risk likelihood and consequence. Finally, models from educational science have been applied to the design of instruction and to evaluation of its impacts on learning, behaviour and risk. Three main models have been leveraged: Instructional Systems Design (ISD); the Kirkpatrick four-levels evaluation model; and a range of techniques for "learner-centred" teaching.

Chapter 3 dealt with the possibilities of deliberate disease in both historical and comparative perspectives. The concepts and the relationships among biosecurity, biosafety, biorisk management, biological weapons, and dual-use have been discussed, with the challenges of defining deliberate disease risks. The identification, characterization and evaluation phases of risk assessment have been explained, including how characterization can be described as “objective but relative”, and evaluation as “subjective”. I explained why I chose three deliberate disease risk scenarios for further discussion: one with state threat; one with non-state outsider threat; and one with non-state insider threat. I also discussed the characterization of hazard, threat and situation factors as well as of types of risk mitigation measures, which can influence likelihood and/or consequence of risks. I then argued what factors could be influenced by education under the three risk scenarios. In Chapter 4, I analysed calls for education applying the historico-political securitization model, looking at securitizing actors, intended audiences, referent objects, and discursive devices. Attempted securitization moves by international governmental organizations, national governments, scientific organizations, academia and civil society have been identified and assessed, mainly directed to States and the scientific community. With Chapters 5 to 9 educational science models were applied to education as a potential security risk mitigation tool.[530] Both the ADDIE and the four-levels models were applied on the education and instruction design plans of the research.[531] Original and pre-existing primary data as well as secondary data were used to illustrate design and evaluation tools. Chapter 5 presented the Analysis phase, including characterization of student audiences and results suggesting that students generally have a low awareness of concepts regarding deliberate disease risks, and that existing educational opportunities are often scarce and insufficient. I discussed how many engaged faculty members from HEIs believe that incorporating education on biosafety and biosecurity is a high priority, and how awareness among educators seems related to heightened interest and commitment to support the implementation of education, which I think supports the value of faculty engagement and instructional design activities. Chapter 6 dealt with Design, the central phase of ISD. Extensive discussion was devoted to the topic of learning objectives, including their features, a taxonomy that integrates cognitive domains and levels of learning, their matching with analysis, and proposed learning objectives for deliberate disease risks mitigation. These were organized in four thematic areas, and I

[530] These Chapters were organized along the phases of the ADDIE model of ISD, integrated with the application of the four-levels impact evaluation model of instruction for the Evaluation phase.

[531] In the education plan the target of interventions are future and young scientists and practictioners. The instruction design plan focuses on instruction for educators of those future and young scientists and practictioners, which is one factor to facilitate the “sustained” component of “effectiveness” of education.

explained how competences in each area contribute to risk mitigation. Finally, the design of evaluation in the education and instruction design plans of the research has been discussed, presenting specific indicators, metrics and possible data sources along the four levels of impact evaluation. Chapter 7 addressed the Development and Implementation phases under the ADDIE model, for both the education and instruction design plans of the research. It mainly focused on the learner-centred teaching pillar of education, including discussion and actual examples from the considered projects of delivery techniques, events of instruction, consideration of learning styles and preferences, learning processes, and examples of instructional materials. Chapter 8 dealt with Evaluation on the education plan, and Chapter 9 with Evaluation on the instruction design plan. This included measuring some of the indicators and applying the evaluation tools proposed earlier in the thesis, presenting results on the four levels of reaction, learning, behaviour and risk, as summarized below.

10.2 Original contributions by the thesis

I think the thesis brings at least three main contributions to knowledge: regarding the constructed role of education as a potential security measure; regarding the employed research framework; and regarding the proposed design and evaluation tools for education to mitigate deliberate disease risks. Firstly, while literature had addressed education and training on risks, security risks, and biosecurity risks, there had not been a structured analysis on the role attributed to education as a security tool in a security arena, and on how the construction of this role happened. This research contributed a securitization discourse analysis that recognized, identified and described securitization attempts on the security role of education.

Secondly, the research framework included, on the one hand, original data and methods of analysis, along existing ones that were used in new ways; it came from more contexts; and it embraced a wider time window than pre-existing works, to come up with new insights on education on deliberate disease risks. Although the research also used data from analyses previously published; previously carried but not published; or carried out by others, it also included entirely original data notably in the form of the semi-structured interviews that provided valuable materials for the discussions on Design and Evaluation. On the other hand, the research framework was original in integrating the conceptual areas of security, risk and education and in proposing ways to connect outcomes in terms of education to outcomes in terms of (security) risks. In this way, I think the methodologically and theoretically informed work in the thesis made a contribution to knowledge.

Thirdly, the thesis proposed some tools, based on the experiences contributing to the research framework, to design and evaluate education that could be effective as a measure to mitigate the security risks of deliberate disease. These tools are based and tested on the data informing the research, advancing a novel contribution to knowledge.

10.3 The research questions revisited

The first research question asked:

> *How was education constructed as a measure to mitigate the security risks of deliberate disease?*

and addressed if, why and how education became a potential measure in an arena traditionally focused on “security”. The thesis argued that education has been constructed, through discursive devices by a number of actors, as one tool to mitigate what were presented as urgent security threats of deliberate disease. Furthermore, the thesis argued that some of the analysed securitization discourses have been effective, to different extents, as they were accepted by their intended audiences and led to new actions and measures. The analysis led to identify six main securitization moves addressed to States and three main securitization moves addressed to scientific communities. Among the former, the moves to recognize the value of education as a risk mitigation measure; on reporting to the BTWC on education efforts; and on funding initiatives and projects on education were successful to different extents. The moves to consider education as part of national implementation of the BTWC; and to involve national organizations competent on education, had mixed success; and the move to develop national and international action plans on education were largely not implemented. Among the latter, the urge on scientists to become aware and recognize the relevance of deliberate disease risks has gradually moved from being resisted to being accepted, though far from widespread implementation. Some actions followed up to the calls to develop and implement education, and to integrate education in higher education systems, however I suggest that implementation has not been widespread or necessarily sustainable.

The second research question asked:

How could education mitigate risks of deliberate disease?

and addressed how the mitigation potential of education on deliberate disease risks could be assessed. The thesis argued that improved competences built with education have the potential to mitigate deliberate disease risks in the three identified risk scenarios by impacting on factors influencing risk likelihood and/or consequence. For example, education could improve capacity on laboratory biorisk management measures, thus impacting on hazard factors and reducing risk likelihood under all three scenarios; it could instil the ethical norm of prohibition of deliberate disease thus impacting on threat factors and reducing risk likelihood under the non-state insider threat scenario; it could introduce responsible management of research with dual-use potential thus impacting on threat factors and reduce risk likelihood under the non-state outsider threat scenario; or could increase the potential for whistleblowing thus impacting on situation factors and reduce risk likelihood under the state threat scenario. It has also been explained how education has a larger potential to mitigate risks through likelihood, rather than consequence, factors. Competences in the (bio)risk management thematic area would have the potential to influence risk in all three reference scenarios. The laboratory biosafety thematic area would have a less direct influence on deliberate disease risks but it would still have the potential to influence risk in the second scenario. The laboratory biosecurity thematic area would have the potential to influence risk in the second and third deliberate disease risk scenarios. The broader biosecurity and dual-use management thematic area would have the potential to influence deliberate disease risks under the three scenarios.

Data from interviews with educators supported the view of this thesis that behavioural change depends on learning, and that learning depends on instruction. Furthermore, evaluation of results supports that education of young and future scientists, specifically in the higher education context, has the potential to mitigate the risks of deliberate disease. Empirical data especially on the levels of behavioural change and results on risks are however still scarce, often due to their long-term nature and to challenges in following-up with students. Nonetheless, I presented some relevant examples of empirical observations on some behavioural and results indicators, some of which were recognized as reasonable developments promoted by education. Analysis of interview material also confirmed the view that education would mitigate deliberate disease risks largely by affecting risk likelihood, and that education has the potential to reduce the likelihood of future and young scientists becoming involved in state programs of developing biological weapons; reduce the likelihood of themselves becoming insider threats, and make them better able to identify and counter insider threats; and mitigate the opportunity for outsider threats to misuse by improving scientists' awareness and capacities to protect their science and to identify and mitigate misuse risks.

Finally, two assumptions connected with the second research question can be reviewed, firstly that education would be considered a measure in the web of prevention of deliberate disease risks, and secondly that, to be able to argue that education has the potential to mitigate deliberate disease risks, the possibility to assess those risks has to be assumed. Regarding the former issue, education has been defined a necessary but not sufficient condition to achieve risk mitigation. Primary data analysis reinforced the idea that components such as legislation and regulatory systems to support scientists in risk management should be integrated in the web of prevention of deliberate disease risks. Regarding the latter issue, the thesis reinforced the idea that factors influencing risks could be characterized, however it didn't try to offer a new characterization (let alone, evaluation) of those factors within a new risk assessment of deliberate disease risks, but rather to identify if education could lower those risks; (some of the) specific risks that could be lowered; and how that could happen.

The third research question asked:

> *What would the tools be to improve effectiveness of education as a mitigation measure of risks of deliberate disease?*

and focused on ways in which education could be designed to maximise potential risks mitigation, have its effects evaluated, and be effective as defined above. The thesis advanced a number of design and evaluation tools that could help in this sense, which were both informed and illustrated by examples from primary and secondary data. Tools included: an application of the ISD approach; an application of instruction evaluation models that define objectives on four levels including reaction, learning, behaviour and result, and that allows evaluating outcomes in terms of education connected to outcomes in terms of risks; applications of what have been termed the "learning-by-design" and the "learner-centred-teaching" pillars of instruction; the engagement of educators and their training in ISD, integrating the instruction design plan to support sustainability; and practical tools such as documents to support design and matrixes with specific indicators, metrics and data sources to support evaluation. I argued that an approach employing some or all of these tools can improve effectiveness of education as a deliberate disease risks mitigation measure, increasing the relevance of built capacities; reaching larger numbers of those who may have a role in mitigating those risks; and improving the likelihood that it is sustained over time.

Presented data contributing to these conclusions include, on the education plan, that testable objectives for the first (reaction) and second (learning) Levels were achieved to acceptable degrees by actions in considered projects. Particularly in the dual-use and broader biosecurity thematic area, being aware of and understanding the dual-use issue is a basic learning objective that was achieved in the experiences that addressed it. Conversations with educators confirmed that the tools could also be valuable to evaluate the third (behaviour) and fourth (results) Levels, and provided data on indicators bringing useful illustrations.

On the instruction design plan, empirical data from projects applying the relevant tools suggested that objectives were achieved, though on different degrees, on reactions and key capacities. I presented data to sustain that actions employing these tools supported the achievement of proposed behavioural indicators, with the initiation of locally driven educational activities. The thesis advanced the idea, supported by educators' views, that sustainability would be improved by formal introduction in educational programs, something making education to mitigate deliberate disease risks a component of instruction. Empirical data suggested that such a level of result was achieved in some situations, and while it would be difficult to irrefutably demonstrate that it was a consequence of the actions employing proposed tools, certainly conversations with involved educators suggested their actions were at least initiated by the work in those projects.

Also, two assumptions connected with the third research question can be reviewed here: the training or non-training nature of problems preventing the transfer from learning to behaviour (and results); and the focus on the higher education context. Regarding the former issue, I argued that education can only ameliorate training problems, and collected data confirmed that other problems may be affecting risk mitigation or preventing improvements from instructional actions, including infrastructure or funding problems; the lack of other necessary components in the web of prevention, such as legislation or support, oversight and reporting systems; rigidity in educational programmes; as well as work environments not receptive to the awareness and capacities that students acquired. Regarding the latter issue, I explained that the focus on higher education had both practical (due to the research situation and the access to data), and theoretical (due to the effectiveness potential) reasons. Findings of the thesis, including what presented on Levels three and four of impact evaluation in both the education and the instruction design plans, are indications to support the value of actions in the higher education context. However, the thesis also underlined that higher education would not be the only possible, and indeed desirable, context for education to mitigate deliberate disease risks, with other channels including continuing professional training – as well as possibly education at the secondary level.[532] The thesis also discussed similarities and differences of the higher education and professional training contexts, as well as how some design and evaluation tools could be applied and adapted beyond higher education, for example regarding the relative importance of the Design and the Development phases.

10.4 Limitations of the research

A number of limitations of the research can also be identified. The nature of the data as discussed could be challenging in terms of reliability, however the explanations on how the data was collected; the level of detail; the triangulation among different methods; and the convergence of general results suggested by

[532] Something advanced and implemented already in the chemical security and chemical weapons risks mitigation field (Hay and Mahaffy, 2013; Schouteten, 2013).

primary and secondary data can mitigate the risks connected with reliability of the results.

Regarding validity, the research had no claim of generalizability from the presented data. What suggested or confirmed by primary data should and could not be generalized to any larger population than the groups and samples it is collected from. Nonetheless, these groups and samples were numerous and diverse and the research presented a very large number of illustrations, examples, experiences and suggestions based on quantitative and qualitative data from a range of contexts and years. Certainly, while the research did leverage experiences in a range of different socio-economic and cultural contexts, as can be gathered from Chapter 1, we cannot irrefutably say if and how much of the results are transferable or dependent on socio-economic and cultural contexts, especially as we have discussed construction of education and that there are training and non-training problems that may strongly depend on social and cultural factors.

A few more specific limitations of the research could be identified on its education and risk mitigation sides. Regarding the former, limitations include empirical data available on higher levels of learning; “skill” and “attitude” cognitive domains; Level three (behaviour) indicators for the education plan, especially in the laboratory biosafety and laboratory biosecurity thematic areas; and experimental design of testing different impacts of learner- and instructor-centred education on learning. The limited availability is probably due to the longer-term nature of the expected effects than the already considerable time window embraced by this research, which anyway brings together more information than any before. Regarding the risk mitigation side, limitations include empirical data available on Level four (results on risks) indicators for the education plan, and the lack of experimental design, due to the research situation and the considered projects. Suggestions to overcome these limitations are included in the next paragraph on possible further research.

10.5 Further research

The experience and findings of the thesis open a number of possible areas that would be interesting to further investigate. These ideas could be arranged into two main categories, firstly specific ones raised by this research which could be checked, tested or further expanded; and secondly more general ideas for further research related to the subject matter and/or to the research framework.

Among specific ideas, firstly it would be interesting to continue tracking the implementation of securitization moves such as considering education (in particular in the context of higher education) as part of national implementation or compliance measures of the BTWC; develop action plans on education; awareness of scientists on deliberate disease risks; and especially integration of education into national systems. Many of these measures, if accepted and feasible at all, would need considerable time for implementation and would be different from country to country and context to context; at the same time, they are still stressed and called by securitizing actors.

Projects considered in this research addressed the four different thematic areas in which I organized the design, development, implementation and evaluation of education in different ways and responding to different priorities and goals. Some actions involved multiple thematic areas, others focused on specific ones. As such, it was not possible to compare and investigate differences in evaluation among the different thematic areas. Designing different thematic areas in an educational action from the beginning, it would be possible to investigate if and how students react better, learn more, and/or transfer to behaviour more successfully regarding laboratory biosafety or dual-use and broader biosecurity, for example; and to control if and how differences are due to the subject matter or to the teaching techniques.

While the research proposed within design and evaluation tools a range of learning objectives and level two indicators, I could provide examples of evaluation on only some of them. Further research would be needed focusing and collecting specific data on learning objectives of the “skill” cognitive domain, including but not necessarily limited to the learning objectives, metrics and possible data sources proposed here. Further research is also suggested that looks at measuring learning objectives and relative indicators, as well as behaviour and results levels, for higher levels of learning. Suggested metrics that could be particularly interesting, and, I think, relatively easy to investigate are “review of research work, proposal and reports” and “integration in work presented at conferences”.

Among more general ideas for further research, firstly the soundness of the research framework could be further tested and possibly refined by applying it to other capacity building contexts. A similar approach connecting outcomes in terms of education to outcomes in terms of risks could be adapted upwards to the context of continuous professional development (in-service training) and downwards to secondary education. Similar design and evaluation tools can also be tested for risk mitigation in areas beyond deliberate disease, biorisks and even security risks.

Regarding both the education and the instruction plans of research, hopefully further research can help in refining the proposed design and evaluation tools that support implementation of relevant, generalized and sustainable education. This should on the one side contribute to risk mitigation, and on the other side not unduly hamper science and technology development.

Bibliography

AAAS (2013) *Bridging Science and Security for Biological Research. International Science and Security. Proceedings from the Meeting. 4-5 February 2013*. Washington, DC: American Association for the Advancement of Science in conjunction with the Association of American Universities, Association of Public and Land-grant Universities, and the Federal Bureau of Investigation.

ABSA (2014) Risk Group Database for infectious agents. *American Biosafety Association*. [Accessed 17 August 2016]. Available from: https://my.absa.org/tiki-index.php?page=Riskgroups.

Adelman, C. (2009) The Bologna Process for US Eyes: Re-learning Higher Education in the Age of Convergence. *Institute for Higher Education Policy*. [Online]. [Accessed 9 August 2016]. Available from: http://eric.ed.gov/?id=ED504904.

Agamben, G. (1998) *Homo sacer: sovereign power and bare life*. Palo Alto: Stanford University Press.

Agius, C. (2013) Social Constructivism *In*: A. Collins, ed. *Contemporary Security Studies*. Oxford and New York: Oxford University Press, pp. 87–103.

Alibek, K. (2008) *Biohazard*. New York: Random House.

Alliger, G.M., Tannenbaum, S.I., Bennett, W., Traver, H. and Shotland, A. (1997) A meta- analysis of the relations among training criteria. *Personnel psychology*. **50**(2),pp.341–358.

Anderson, F.W., Obed, S.A., Boothman, E.L. and Opare-Ado, H. (2014) The public health impact of training physicians to become obstetricians and gynecologists in Ghana. *American journal of public health*. **104**(S1),pp.S159–S165.

Andrews, D.H. (1980) A comparative analysis of models of instructional design. *Journal of Instructional Development*. **3**(4),pp.2–16.

Andrews, D.H. and Goodson, L.A. (1980) A comparative analysis of models of instructional design. *Journal of instructional development*. **3**(4),pp.2–16.

Apostolakis, G.E. (2004) How Useful Is Quantitative Risk Assessment? *Risk Analysis*. **24**(3),pp.515–520.

Armbruster, P., Patel, M., Johnson, E. and Weiss, M. (2009) Active learning and student-centered pedagogy improve student attitudes and performance in introductory biology. *CBE-Life Sciences Education*. **8**(3),pp.203–213.

Arsenic Biosensor Collaboration 2013. *Arsenic Biosensor*. [Accessed 1 August 2016]. Available from: http://www.arsenicbiosensor.org/.

Arthur Jr, W., Bennett Jr, W., Edens, P.S. and Bell, S.T. (2003) Effectiveness of training in organizations: a meta-analysis of design and evaluation features. *Journal of Applied psychology*. **88**(2),p.234.

ASM (2005) Code of ethics. American Society for Microbiology. [Accessed 18 August 2016]. Available from: http://www.asm.org/ccLibraryFiles/FILENAME/000000001596/ASMCodeofEthics05.pdf.

ASSOBIOTEC (2013) Valori Etici Fondamentali dell'Industria Biotecnologica. *http://assobiotec.federchimica.it*. [Accessed 21 August 2016]. Available from: http://assobiotec.federchimica.it/docs/default-source/allegati/mission/valori-etici.pdf.

AstraZeneca (2014) Code of Conduct. [Accessed 4 August 2016]. Available from: https://www.astrazeneca.com/content/dam/az/our-company/Documents/Code-in-English.pdf.

Astuto Gribble, L., Sangalang Tria, E. and Wallis, L. (2015) The AMP model *In*: R. M. Salerno and J. M. Gaudioso, eds. *Laboratory biorisk management: biosafety and biosecurity*. Boca Raton London New York: CRC Press, Taylor & Francis Group, pp. 31–44.

Atlas, R.M. and Dando, M.R. (2006) The Dual Use Dilemma in the Life Sciences. *Biosecurity and Bioterrorism: Biodefense Strategy, Practice and Science*. **4**(3),pp.276–286.

AusBiotech (2005) Biotechnology Industry Code of Conduct. [Accessed 18 August 2016]. Available from: http://www.ausbiotech.org/UserFiles/File/Code-of-Conduct.pdf.

Austin, J.L. (1962) *How to Do Things With Words*. Oxford and New York: Oxford University Press.

Australia, Canada, Japan, New Zealand, Republic of Korea (on behalf of the 'JACKSNNZ'), Switzerland, Kenya, Sweden and Ukraine (2011) *Possible Approaches to Education and Awareness Raising among Life Scientists. Working Paper. BWC/CONF.VII/WP.20*. Geneva: Biological and Toxin Weapons Convention.

Australia, Canada, Japan, New Zealand and Switzerland (2012) *We Need to Talk About Compliance. Working Paper. BWC/MSP/2012/WP.11*. Geneva: Biological and Toxin Weapons Convention.

Australia Group (2013) Australia Group Website. [Accessed 30 August 2013]. Available from: http://www.australiagroup.net/en/index.html.

Austria (2015) *Biosafety and biosecurity: today's challenges for politics and science. Report from a seminar held on 25 June 2015 in Vienna. Working Paper. BWC/MSP/2015/WP.2.* Geneva: Biological and Toxin Weapons Convention.

Aven, T. (2011) On Different Types of Uncertainties in the Context of the Precautionary Principle. *Risk Analysis*. **31**(10),pp.1515–1525.

Aven, T. (2007) On the Ethical Justification for the Use of Risk Acceptance Criteria. *Risk Analysis*. **27**(2),pp.303–312.

Aven, T. and Zio, E. (2014) Foundational Issues in Risk Assessment and Risk Management: Perspectives. *Risk Analysis*. **34**(7),pp.1164–1172.

Ayoob, M. (1997) Defining security: a subaltern realist perspective *In*: K. Krause and M. C. Williams, eds. *Critical Security Studies. Concepts and Cases*. London: UCL Press, pp. 121–146.

Bacon, F. (1858) *The Works of Francis Bacon, Bafron of Verulam, Viscount St. Alban, and Lord High Chancellor of England: Literary and professional Works. Daedalus or the Mechanic*. London: Longman's.

Balmer, B. (2006) The UK Biological Weapons Program *In*: M. Wheelis, L. Rózsa and M. R. Dando, eds. *Deadly cultures: biological weapons since 1945*. Cambridge and London: Harvard Univ. Press, pp. 47–83.

Balzacq, T. (2010) Constructivism and Securitization Studies *In*: V. Mauer and M. D. Cavelty, eds. *The Routledge Handbook of Security Studies*. London: Routledge.

Banathy, B.H. (1987) Instructional Systems Design *In*: *Instructional technology: foundations*. Hillside, NJ: Lawrence Earlbaum Associates, pp. 85–112.

Bassi, L.J. and Van Buren, M.E. (1999) The 1999 ASTD state of the industry report. *Training & development*. **53**(1),pp.S3–S3.

Bates, R. (2004) A critical analysis of evaluation practice: the Kirkpatrick model and the principle of beneficence. *Evaluation and Program Planning*. **27**(3),pp.341–347.

BBC (2001) Britain's 'Anthrax Island'. *BBC News*. [Accessed 30 August 2016]. Available from: http://news.bbc.co.uk/2/hi/uk_news/scotland/1457035.stm.

Beck, U. (2013) *World at Risk*. London: Wiley.

Beck, U. (2002a) The cosmopolitan society and its enemies. *Theory, culture & society*. **19**(1-2),pp.17–44.

Beck, U. (2002b) The terrorist threat world risk society revisited. *Theory, culture & society*. **19**(4),pp.39–55.

Beck, U. (1992) *Risk Society: Towards a New Modernity*. Los Angeles, CA: SAGE Publications.

Beck, U., Giddens, A. and Lash, S. (1994) *Reflexive modernization: Politics, tradition and aesthetics in the modern social order*. Palo Alto: Stanford University Press.

Benin (2013) *BWC - Meeting of Experts. Geneva, 12-16 August 2013. Monday, 12 August 2013. Statement by Benin. Transcript of the English interpretation.* Geneva: Biological and Toxin Weapons Convention.

Berelson, B. (1952) *Content analysis in communication research*. New York: Free Press.

Berg, P., Baltimore, D., Brenner, S., Roblin, R.O. and Singer, M.F. (1975) Summary statement of the Asilomar conference on recombinant DNA molecules. *Proceedings of the National Academy of Sciences*. **72**(6),pp.1981–1984.

Bezuidenhout, L. (2014) Moving Life Science Ethics Debates Beyond National Borders: Some Empirical Observations. *Science and Engineering Ethics*. **20**(2),pp.445–467.

Bezuindenhout, L. and Rappert, B. (2012) The Ethical Issues of Dual-Use and the Life Sciences. *CORE Issues*. **1**(1).

Bigo, D. (2008) Security: A Field Left Fallow *In*: M. Dillon and A. W. Neal, eds. *Foucault on Politics, Security and War*. London: Palgrave MacMillan, pp. 93–114.

Bloom, B.S. (1956) *Taxonomy of educational objectives: the classification of educational goals*. Philadelphia: McKay.

Bober, C.F. and Bartlett, K.R. (2004) The utilization of training program evaluation in corporate universities. *Human Resource Development Quarterly*. **15**(4),pp.363–383.

Bojtzov, V. and Geissler, E. (1999) Military Biology in the USSR, 1920-45 *In*: E. Geissler and J. E. von Courtland Moon, eds. *Biological and Toxin Weapons: Research, Development and Use from the Middle Ages to 1945*. SIPRI Chemical & Biological Warfare Studies. Oxford and New York: Oxford University Press, pp. 153–167.

Bokan, S. and Orahovec, Z. (2004) An Evaluation of Bioregulators/Modulators as Terrorism and Warfare Agents *In*: *Technology for Combating WMD Terrorism*. Springer, pp. 29–40.

Bologna Working Group (2005) *A Framework for Qualifications of the European Higher Education Area. Bologna Working Group Report on Qualifications Frameworks*. Copenhagen: Danish Ministry of Science, Technology and Innovation. [Accessed 30 August 2016]. Available from: http://ecahe.eu/w/images/7/76/A_Framework_for_Qualifications_for_the_European_Higher_Education_Area.pdf.

Bonner, J. (1982) Systematic lesson design for adult learners. *Journal of instructional development*. **6**(1),pp.34–42.

Booth, K. (2005) Critical Explorations *In*: K. Booth, ed. *Critical Security Studies And World Politics*. Boulder: Lynne Rienner Publishers, pp. 1–18.

Bowers, C.A., Morgan, B.B., Salas, E. and Prince, C. (1993) Assessment of coordination demand for aircrew coordination training. *Military Psychology*. **5**(2),pp.95–112.

Boyer, E.L. and Hechinger, F.M. (1981) *Higher Learning in the Nation's Service. A Carnegie Foundation Essay.* ERIC.

Boyle, T. (2008) *Health and safety: risk management*. Wigston: IOSH Services.

Bradbury, J.A. (1989) The Policy Implications of Differing Concepts of Risk. *Science, Technology & Human Values*. **14**(4),pp.380–399.

Branson, R.K. 1978. The interservice procedures for instructional systems development. *Educational Technology*. **3**(4),pp.2–16.

Branson, R.K., Wagner, B.M. and Rayner, G.T. (1977) *Interservice Procedures for Instructional Systems Development: Task V Final Report*. Tallahassee: Center for Educational Technology, Florida State University. [Accessed 9 August 2016]. Available from: http://eric.ed.gov/?id=ED164745.

Brashear, J.P. and Jones, J.W. (2010) Risk Analysis and Management for Critical Asset Protection (RAMCAP Plus) *In*: *Wiley Handbook of Science and Technology for Homeland Security*. Hoboken, NJ, USA: John Wiley & Sons, Inc.

Brazil (2008) *National Measures and Views on Biosafety and Biosecurity. Working Paper. BWC/MSP/2008/MX/WP.28*. Geneva: Biological and Toxin Weapons Convention.

Brenner, J. (2007) ISO 27001: Risk management and compliance. *Risk management*. **54**(1),p.24.

British Medical Association (1999) *Biotechnology, Weapons, and Humanity*. London: Harwood Acad. Publ.

Brown, G.G. and Cox Jr., L.A.T. (2011) How Probabilistic Risk Assessment Can Mislead Terrorism Risk Analysts: How PRA Can Mislead Terrorism Risk Analysts. *Risk Analysis*. **31**(2),pp.196–204.

Bryman, A. (2006) Integrating quantitative and qualitative research: how is it done? *Qualitative Research*. **6**(97),pp.97–113.

Bryman, A. (1998) *Quantity and Quality in Social Research*. London and New York: Routledge.

BTWC (2014) *Meeting of States Parties to the Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction. Report. BWC/MSP/2014/5*. Geneva: Biological and Toxin Weapons Convention.

BTWC (2013) *Meeting of States Parties to the Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction. Report. BWC/MSP/2013/5*. Geneva: Biological and Toxin Weapons Convention.

BTWC (2012a) *Meeting of States Parties to the Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction. Report. BWC/MSP/2012/5*. Geneva: Biological and Toxin Weapons Convention.

BTWC (2012b) *Seventh Review Conference of the Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction. Final Document. BWC/CONF.VII/7*. Geneva: Biological and Toxin Weapons Convention.

BTWC (2008a) *Meeting of Experts of the States Parties to the Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction. Report. BWC/MSP/2008/MX/3*. Geneva: Biological and Toxin Weapons Convention.

BTWC (2008b) *Meeting of States Parties to the Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and*

Toxin Weapons and on their Destruction. Report. BWC/MSP/2008/5. Geneva: Biological and Toxin Weapons Convention.

BTWC (2006) *Sixth Review Conference of the States Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction (Geneva, 20 November - 8 December 2006). Final Document. BWC/CONF.VI/6*. Geneva: Biological and Toxin Weapons Convention.

BTWC (2005a) *Existing Codes of Conduct which Refer to Biological and Toxin Weapons. Summary of Background Paper prepared by the Secretariat. BWC/MSP/2005/MX/INF.1/Summary.* Geneva: Biological and Toxin Weapons Convention.

BTWC (2005b) *Meeting of Experts of the States Parties to the Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction. Report. BWC/MSP/2005/MX/3*. Geneva: Biological and Toxin Weapons Convention.

BTWC (2005c) *Meeting of States Parties to the Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction. Report. BWC/MSP/2005/3*. Geneva: Biological and Toxin Weapons Convention.

BTWC (2003a) *Meetings of States Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destrution. Report Volume I. Part I. BWC/MSP/2003/4 (Vol. I)*. Geneva: Biological and Toxin Weapons Convention.

BTWC (2003b) *Meetings of States Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destrution. Volume II. Annex II. Statements, Presentations and Contributions made available to the Chairman. Report. BWC/MSP/2003/4 (Vol. II)*. Geneva: Biological and Toxin Weapons Convention.

BTWC (1996) *Fourth Review Conference of the Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction. Final Document. Part II Final Declaration. BWC/CONF.IV/9 Part II*. Geneva: Biological and Toxin Weapons Convention.

BTWC (1993) *Ad Hoc Group of Governmental Experts to Identify and Examine Potential Verification Measures from a Scientific and Technical Standpoint. Summary Report. BWC/CONF.III/VEREX/8.* Geneva: Biological and Toxin Weapons Convention.

BTWC (1991) *Third Review Conference of the Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction. Final Document. Part II Final Declaration. BWC/CONF.III/23 Part II*. Geneva: Biological and Toxin Weapons Convention.

BTWC (1986) *Second Review Conference of the Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction. Final*

Document. Part II. Final Declaration. BWC/CONF.II/13/II. Geneva: Biological and Toxin Weapons Convention.

Buganza, T., Kalchschmidt, M., Bartezzaghi, E. and Amabile, D. (2013) Measuring the impact of a major project management educational program: The PMP case in Finmeccanica. *International Journal of Project Management*. **31**(2),pp.285–298.

Burr, V. (2015) *Social constructionism* [ebook] 3. ed. London: Routledge.

Buzan, B. (1991) *People, States & Fear*. Colchester: ECPR Press.

Buzan, B., Wæver, O. and de Wilde, J. (1998) *Security: A New Framework for Analysis*. Boulder, CO: Lynne Rienner Pub.

Canada (2012) *Considerations and recommendations to inculcate awareness of the dual-use challenge into biosafety and biosecurity training and education for life scientists in States Parties. Working Paper. BWC/MSP/2012/WP.4.* Geneva: Biological and Toxin Weapons Convention.

Canada (2005) *Thoughts on the Functions of Codes of Conduct: Potential Weaknesses and Solutions. BWC/MSP/2005/MX/WP.6*. Geneva: Biological and Toxin Weapons Convention.

Cannon-Bowers, J.A. and Salas, E. (1998) Individual and team decision making under stress: Theoretical underpinnings. *In*: J. A. Cannon-Bowers and E. Salas, eds. *Making decisions under stress: Implications for individual and team training.* Washington: American Psychological Association, pp. 17–38.

Carlson, R.H. (2003) The pace and proliferation of biological technologies. *Biosecurity and Bioterrorism: Biodefense Strategy, Practice and Science.* **1**(3),pp.203–14.

Carlson, R.H. (2010) *Biology Is Technology*. Cambridge, MA: Harvard Univ. Press.

Carus, W.S. (2002) *Bioterrorism and Biocrimes*. Washington, DC: National Defense University, Center for Counterproliferation Research.

Caskey, S., Gaudioso, J., Salerno, R.M., Wagener, S., Shigematsu, M., Risi, G., Kozlovac, J. and Halkjaer-Knudsen, V. (2010) *Biosafety Risk Assessment Methodology. SAND2010-6487*. Albuquerque, NM: Sandia National Laboratories.

Caskey, S. and Sevilla-Reys, E.E. (2015) Risk Assessment *In*: R. M. Salerno and J. M. Gaudioso, eds. *Laboratory biorisk management: biosafety and biosecurity*. Boca Raton London New York: CRC Press, Taylor & Francis Group, pp. 45–64.

Caygill, H. (2000) Liturgies of Fear: Biotechnology and Culture *In*: *The Risk Society and Beyond: Critical Issues for Social Theory*. London: SAGE Publications.

CBUI (2008) Report of the Meeting of the Directing Committee of CBUI, 6 November 2008 (in Italian). *Consiglio dei Biologi delle Università Italiane*. [Accessed 21 August 2016]. Available from:

http://www.cbui.it/joomla/images/verbali%20e%20documenti/2008/07_verbale_CD_06_11_2008.pdf.

CBUI (2009) Report of the Meeting of the Directing Committee of CBUI, 15 May 2009 (in Italian). *Consiglio dei Biologi delle Università Italiane*. [Accessed 30 August 2016]. Available from: http://www.cbuit.it/joomla/images/verbali%20e%20documenti/2009/05_verbale_CD_15_05_2009.pdf.

CEN (2011) *CEN Workshop Agreement CWA15793. Laboratory biorisk management*. Paris: Comité Europeén de Normalization.

Charrett, C. (2009) *A Critical Application of Securitization Theory: Overcoming the Normative Dilemma of Writing Security*. Barcelona: International Catalan Institute for Peace.

Chile, Colombia, Spain, Italy and Mexico (2012) *'Código de Conducta para Científicos'. Working Paper. BWC/MSP/2012/WP.9.* Geneva: Biological and Toxin Weapons Convention.

Clevestig, P. (2009) *Handbook of applied biosecurity for life science laboratories*. Stockholm: Stockholm International Peace Research Institute (SIPRI).

Colliver, J.A. 2000. Effectiveness of problem-based learning curricula: research and theory. *Academic Medicine*. **75**(3),pp.259–266.

Commission on the Prevention of Weapons of Mass Destruction Proliferation and Terrorism, Graham, B., Talent, J. and Allison, G.T. (2008) *World at risk: the report of the Commission on the Prevention of WMD Proliferation and Terrorism*. New York: Vintage Books.

Connell, N. and McCluskey, B. (2010) Bringing Biosecurity-related Concepts into the Curriculum: A US View *In*: B. Rappert, ed. *Education and Ethics in the Life Sciences*. Canberra: ANU E Press, pp. 149–161.

Convention on Biological Diversity 2016. Frequently Asked Questions (FAQs) on the Cartagena Protocol. [Accessed 8 August 2016]. Available from: http://bch.cbd.int/protocol/cpb_faq.shtml.

Coomber, R. (1997) Using the Internet for survey research. *Sociological Research Online*. **2**(2). [Accessed 8 March 2016]. Available from: http://www.socresonline.org.uk/2/2/2.html.

Council of the European Union (2009) *Council conclusions on strenghtening chemical, biological, radiological and nuclear (CBRN) security in the European Union - an EU CBRN Action Plan. 15505/1/09. Annex I*. [Accessed 9 June 2012]. Available from: http://europa.eu/legislation_summaries/justice_freedom_security/fight_against_terrorism/jl0030_en.html.

van Courtland Moon, J.E. (2006) The US Biological Weapons Program *In*: M. Wheelis, L. Rózsa and M. R. Dando, eds. *Deadly cultures: biological weapons since 1945*. Cambridge and London: Harvard Univ. Press, pp. 9–46.

van Courtland Moon, J.E. (1999) US Biological Warfare Planning and Preparedness: the Dilemmas of Policy *In*: *Biological and Toxin Weapons: Research, Development and Use from the Middle Ages to 1945*. SIPRI Chemical & Biological Warfare Studies. Oxford and New York: Oxford University Press, pp. 215–254.

van Courtland Moon, J.E., Carter, G.B. and Pearson, G.S. (1999) British Biological Warfare and Biological Defence, 1925-45 *In*: E. Geissler and J. E. von Courtland Moon, eds. *Biological and Toxin Weapons: Research, Development and Use from the Middle Ages to 1945*. SIPRI Chemical & Biological Warfare Studies. Oxford and New York: Oxford University Press, pp. 168–189.

Cox, L.A.T. (2008) Some Limitations of 'Risk = Threat × Vulnerability × Consequence' for Risk Analysis of Terrorist Attacks. *Risk Analysis*. **28**(6),pp.1749–1761.

Creswell, J.W. (2003) *Research design: Qualitative, quantitative, and mixed methods approaches* 2nd ed. Thousands Oaks, London and New Delhi: SAGE Publications.

CSIC (2016) Webometrics Ranking of World Universities. *Consejo Superior de Investigaciones Científicas (CSIC)*. [Online]. [Accessed 8 July 2016]. Available from: http://www.webometrics.info/en/About_Us.

Cuba (2008) *Intervenciòn Delegaciòn de Cuba. Tema 1: Medidas Nacionales, regionales e internacionales para mejorar la bioseguridad y la protecciòn en los laboratorios de patògenos y toxinas. Subtema: Bioseguridad y Bioprotecciòn: Conceptos y enfoques.* Geneva: Biological and Toxin Weapons Convention.

Cuba (on behalf of NAM) (2008) *Statement by Mr. Oscar Leon Gonzalez, Member of the Delegation of the Republic of Cuba, on behalf of the Group of Non-Aligned Movement and other States Parties to the Biological Weapons Convention at the 2008 Meeting of Experts. Geneva, 18 August 2008*. Geneva: Biological and Toxin Weapons Convention.

Dando, M.R. (2009a) Biologists napping while work militarized. *Nature*. **460**(7258),pp.950–951.

Dando, M.R. (2009b) *Bioterror and Biowarfare*. Oxford: One World Publications.

Dando, M.R. and Rappert, B. (2005) Codes of Conduct for the Life Sciences: Some Insights from UK Academia. *Bradford Briefing Papers on Strenghtening the Biological Weapons Convention, Second Series*. **16**(Second Series).

Davison, N. (2009) *'Non-Lethal' Weapons*. Basingstoke and New York: Palgrave Macmillan.

De Felice, M., Giuliani, A.R., Alfonsi, G., Mosca, G. and Fabiani, L. (2008) Survey of nursing knowledge on bioterrorism. *International Emergency Nursing*. **16**(2),pp.101–108.

Delarosa, P., Kennedy, S., Jones, M., Kinsey, M. and Gardiner, L. (2011) Quantifying Competency in Biosafety: Adaption of the Instructional Systems Design Methodology (ISD) to Biosafety and Laboratory Biosecurity. *Applied biosafety*. **16**(3),pp.177–183.

Depoy, J., Phelan, J., Sholander, P., Smith, B., Varnado, G.B. and Wyss, G. (2005) Risk assessment for physical and cyber attacks on critical infrastructures *In*: *MILCOM 2005-2005 IEEE Military Communications Conference*. IEEE, pp. 1961–1969.

Deutscher Ethikrat (2014) *Biosecurity — Freedom and Responsibility of Research*. Berlin: German Ethics Council. Available from: http://www.ethikrat.org/files/opinion-biosecurity.pdf.

De Vaus, D.A. (2001) *Surveys in social research* 5th ed. London: Routledge.

DeYoung, A.G. and Gearan A. (2012) Obama's 'Red Line' Warning to Syria on Chemical Arms Draws Criticism. *The Washington Post*. 21 August 2012.

Dillman, D.A., Smyth, J.D. and Christian, L.M. (2009) *Internet, mail, and mixed-mode surveys: the tailored design method* 3. ed. Hoboken, NJ: Wiley.

Dillon, M. and Neal, A.W. (2011) *Foucault on Politics, Security and War*. Basingstoke and New York: Palgrave MacMillan.

Dixon, N.M. (1990) The relationship between trainee responses on participant reaction forms and posttest scores. *Human Resource Development Quarterly*. **1**(2),pp.129–137.

Domaradskij, I.V. and Orent, W. (2006) Achievements of the Soviet biological weapons programme and implications for the future. *Scientific and Technical Review of the Office International des Epizooties*. **25**(1),pp.153–161.

Douglas, M. (1998) *Purezza e pericolo: un'analisi dei concetti di contaminazione e tabu*. Bologna: Il mulino.

Douglas, M. (1992) *Risk and blame essays in cultural theory*. London and New York: Routledge.

Douglas, M. (1985) *Risk Acceptability According to the Social Sciences*. New York, NY: Russell Sage Foundation.

Du, Q.-L., Cao, S.-M., Ba, L.-L. and Cheng, J.-M. (2008) Application of PDCA Cycle in the Performance Management System *In*: *2008 4th International Conference on Wireless Communications, Networking and Mobile Computing. Dalian. 12-14 October 2008*, pp. 1–4.

Edmonds, G.S., Branch, R.C. and Mukherjee, P. (1994) A conceptual framework for comparing instructional design models. *Educational Technology Research and Development*. **42**(4),pp.55–72.

EFE (2009) El mal uso de las armas biològicas puede acabar en catàstrofe, segùn los expertos. *La Opiniòn de Granada*. 30 September 2009,p.10.

Ehni, H.-J. (2008) Dual use and the ethical responsibility of scientists. *Archivum Immunologiae et Therapiae Experimentalis*. **56**(3),pp.147–152.

Elbe, S. (2010) *Security and Global Health*. New York: Wiley.

Elbe, S. (2005) AIDS, Security, Biopolitics. *International Relations*. **19**(4),pp.403–419.

Ely, D. (1992) *Trends in Educational Technology*. Syracuse, NY: ERIC Clearinghouse on Information Resources.

Emmers, R. (2013) Securitization *In*: A. Collins, Alan, ed. *Contemporary Security Studies*. Oxford and New York: Oxford University Press, pp. 131–146.

Enemark, C. (2010) Raising Awareness among Australian Life Scientists *In*: B. Rappert, ed. *Education and Ethics in the Life Sciences*. Canberra: ANU E Press, pp. 131–148.

Eriksson, J. (1999) Observers or Advocates?: On the Political Role of Security Analysts. *Cooperation and Conflict*. **34**(3),pp.311–330.

Espona, M.J. and Dando, M.R. (2011) *Dual-Use Bioethics for the Life Sciences: The Development of a Country-Specific Short Course Template and a Trial Application to Argentina*. Bradford: Department of Peace Studies, University of Bradford.

EuropaBio (2016) Core Ethical Values. *europabio.org*. [Online]. [Accessed 2 September 2016]. Available from: http://www.europabio.org/cross-sector/publications/core-ethical-values.

European Agency for Safety and Health at Work (2014) *Exposure to carcinogens and work-related cancer: A review of assessment methods. European Risk Observatory Report.* Luxembourg: Publications Office of the European Union.

European Commission (2010a) *COM(2010)380 final. Communication From The Commission To The European Parliament, The Council, The Economic And Social Committee And The Committee Of The Regions On The Freedom For Member States To Decide On The Cultivation Of Genetically Modified Crops* [Online]. Available from: http://ec.europa.eu/food/food/biotechnology/docs/communication_en.pdf.

European Commission (2010b) *SEC(2010)1626 final. Commission Staff Working Paper. Risk Assessment and Mapping Guidelines for Disaster Management.* European Commission.

European Commission (2007) COM(2007)399 final. Green Paper on Biopreparedness. Presented by the Commission. [Accessed 9 June 2016]. Available from: http://ec.europa.eu/food/resources/gp_bio_preparedness_en.pdf.

European Commission (2009) *COM(2009) 273 final. Communication from the Commission to the European Parliament and the Council on Strengthening Chemical, Biological, Radiological and Nuclear Security in the European Union - an EU CBRN Action Plan*. [Accessed 9 June 2012]. Available from: http://europa.eu/legislation_summaries/justice_freedom_security/fight_against_terrorism/jl0030_en.html.

European Group on Ethics in Science and New Technologies to the European Commission (2010) *Ethics of Synthetic Biology*. Luxembourg: Publications Office of the European Union. [Accessed 9 June 2012]. Available from: http://ec.europa.eu/bepa/european-group-ethics/docs/opinion25_en.pdf.

European Union (2001) Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC - Commission Declaration. *Official Journal of the European Union*.,pp.1–39.

European Union (2009) Council Regulation (EC) No 428/2009 of 5 May 2009 setting up a Community regime for the control of exports, transfer, brokering and transit of dual-use items. *Official Journal of the European Union*,pp.1–269.

European Union (2000) Directive 2000/54/EC of the European Parliament and of the Council of 18 September 2000 on the protection of workers from risks related to exposure to biological agents at work. *Official Journal of the European Union*,pp.21–45.

Ezell, B.C., Bennett, S.P., von Winterfeldt, D., Sokolowski, J. and Collins, A.J. (2010) Probabilistic Risk Analysis and Terrorism Risk. *Risk Analysis*. **30**(4),pp.575–589.

Fair, J.M., Stokes, M.M., Pennington, D. and Mendenhall, I.H. (2016) Scientific Collaborations: How Do We Measure the Return on Relationships? *Frontiers in Public Health*. **4**. [Accessed 9 August 2016]. Available from: http://journal.frontiersin.org/Article/10.3389/fpubh.2016.00009/abstract.

FAO (2016) Biosecurity for Agriculture and Food Production. [Accessed 8 August 2016]. Available from: http://www.fao.org/biosecurity/.

FAS (2009) *Federation of American Scientists Case Studies in Dual Use Biological Research*. Federation of American Scientists. [Accessed: 2 September 2016]. Available from: https://fas.org/biosecurity/education/dualuse/

Feakes, D., Rappert, B. and McLeish, C. (2007) Introduction: A Web of Prevention? *In*: C. McLeish and B. Rappert, eds. *A Web of Prevention: Biological Weapons, Life Sciences, and the Governance of Research*. London: Routledge, pp. 1–14.

Felder, R.M. and Silverman, L.K. (1988) Learning and teaching styles in engineering education. *Engineering education*. **78**(7),pp.674–681.

Fidler, D.P. (2007a) A pathology of public health securitism: approach pandemics as security threats *In*: A. J. Cooper, J. J. Kirton and T. Schrecker, eds. *Governing Global Health: Challenge, Response, Innovation*. Aldershot: Ashgate Publishing, p. Chapter 4.

Fidler, D.P. (2007b) Governing catastrophes: security, health and humanitarian assistance. *International Review of the Red Cross*. **89**(866),pp.247–270.

Fidler, D.P. and Gostin, L.O. (eds.). (2008) *Biosecurity in the Global Age: Biological Weapons, Public Health, and the Rule of Law*. Palo Alto: Stanford University Press.

Fierke, K. (1997) Changing Worlds of Security *In*: K. Krause and M. C. Williams, eds. *Critical Security Studies. Concepts and Cases*. London: UCL Press, pp. 223–254.

Foreign & Commonwealth Office (2013) *Global Partnership Against the Spread of Materials and Weapons of Mass Destruction: President's Report for 2013*. London: Foreign & Commonwealth Office. [Accessed 18 August 2016]. Available from:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/269504/UK_2013_GP_Report.pdf.

Foreign & Commonwealth Office (2002) *Strenghtening the Biological and Toxin Weapons Convention: Countering the Threat from Biological Weapons. Presented to Parliament by the Secretary of State for Foreign and Commonwealth Affairs*. London: Foreign and Commonwealth Office.

Foucault, M. (2004) *L'ordine del discorso*. Torino: Einaudi.

Foucault, M. (2002) *Archaeology of Knowledge*. New York: Routledge.

Foucault, M., Marchetti, V. and Salomoni, A. (2002) *Gli anormali. Corso al Collège de France (1974-1975)*. Milano: Feltrinelli.

Foucault, M. and Napoli, P. (2005) *Sicurezza, territorio, popolazione. Corso al Collège de France (1977-1978)*. Milano: Feltrinelli.

Foucault, M. and Zini, V. (2005) *Nascita della biopolitica: corso al Collège de France (1978-1979)*. Milano: Feltrinelli.

Fox, N. (1998) 'Risks', 'Hazards' and Life Choices: Reflections on Health at Work. *Sociology*. **32**(4),pp.665–687.

France (2012) *Etude de l'UNIDIR sur la création d'un mécanisme de revue par les pairs dans le cadre de la Convention d'interdiction des armes biologiques et à toxines. Présenté par la France. Working Paper. BWC/MSP/2012/WP.12*. Geneva: Biological and Toxin Weapons Convention.

France (2008) *Les Initiatives de L'Union Européenne en soutien a la mise en oeuvre et a l'universalisation de la Convention sur l'interdition des armes biologiques (CIAB), y compris les aspects de bio-securité et de bio-sureté. Working Paper. BWC/MSP/2008/WP .4*. Geneva: Biological and Toxin Weapons Convention.

Franzosi, R. (2008) *Content analysis. Volume I. What is content analysis? Defining the methodological playing field*. Thousands Oaks, London and New Delhi: SAGE Publications.

Freeman, S., Eddy, S.L., McDonough, M., Smith, M.K., Nnadozie, O. and Jordt, H. (2014) Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*. **111**(23),pp.8410–8415.

Fricker, Jr., R.D. (2008) Sampling methods for web and e-mail surveys *In*: M. Fielding and G. Blank, eds. *The SAGE handbook of Online Research Methods*. Thousands Oaks, London and New Delhi: SAGE Publications, pp. 195–216.

Furmanski, M. and Wheelis, M. (2006) Allegations of Biological Weapons Use *In*: M. Wheelis, L. Rózsa and M. R. Dando, eds. *Deadly cultures: biological weapons since 1945*. Cambridge and London: Harvard Univ. Press, pp. 252–282.

Furukawa, K. (2011) Case Study I: the Aum Shinrikyo's biological weapons terrorism in Japan *In*: P. Millett, ed. *Improving Implementation of the Biological*

Weapons Convention. The Intersessional Process. Geneva: United Nations Disarmament Institute, pp. 121–126.

G8 (2011) *G8 Summit 2011. The Global Partnership: Assessment and Options for Future Programming*. Deauville: G8 Global Partnership.

G8 (2009) *L'Aquila Statement on Non Proliferation ANNEX B: Recommendations for a coordinated approach in the field of Global WMD Knowledge proliferation and scientists engagement*. L'Aquila: G8 Global Partnership. [Accessed 18 August 2016]. Available from: http://www.g8italia.it/static/G8_Allegato/2._LAquila_Statent_on_Non_proliferation.pdf.

G8 (2002) *Statement by G8 Leaders The G8 Global Partnership Against the Spread of Weapons and Materials of Mass Destruction*. Kananaskis: G8 Global Partnership. [Accessed 18 August 2016]. Available from: http://www.g8.utoronto.ca/summit/2002kananaskis/arms.html.

Gagné, R.M., Briggs, L.J. and Wager, W.W. (1992) *Principles of Instructional Design* 4th ed. Forth Worth, TX: Harcourt Brace College Publishers.

Gagné, R.M. and Rohwer, W.D. (1969) Instructional psychology. *Annual Review of Psychology*. **20**(1),pp.381–418.

Gardner, H. (2011) *Frames of Mind: The Theory of Multiple Intelligences*. New York: Basic Books.

Garrick, B.J. (2008) *Quantifying and Controlling Catastrophic Risks*. Waltham: Academic Press.

Gaudioso, J., Caskey, S., Burnett, L., Heegaard, E., Owens, J. and Stroot, P. (2009) *Strengthening Risk Governance in Bioscience Laboratories. SAND2009-8070*. Albuquerque, NM: Sandia National Laboratories.

Geissler, E. (2001) Prevention of Biological Warfare: What Can We Learn from History? *In*: *Biological Warfare*. Delhi: Discovery Publishing House, pp. 169–184.

Germany (2005) *Codes of Conduct and their Application in the Life Sciences at Universities. Working Paper. BWC/MSP/2005/MX/WP.12*. Geneva: Biological and Toxin Weapons Convention.

Ghodsian, D., Bjork, R.A. and Benjamin, A.S. (1997) Evaluating Training During Training: Obstacles and Opportunities *In*: M. A. Quinones and A. Ehrenstein, eds. *Training for 21st Century Technology: Applications of Psychological Research*. Washington, DC: American Psychological Association, pp. 63–88.

Giddens, A. (1999) Risk and responsibility. *The modern law review*. **62**(1),pp.1–10.

Giddens, A. (1991) *Modernity and Self-identity: Self and Society in the Late Modern Age*. Palo Alto: Stanford University Press.

Glaser, C.L. (2013) Realism. In: Alan Collins, Alan (ed.). *Contemporary Security Studies*. 3rd edition. Oxford and New York, Oxford University Press. pp. 13–27.

Goettl, B.P., Yadrick, R.M., Connolly-Gomez, C., Regian, W.J. and Shebilske, W.L. (1996) Alternating task modules in isochronal distributed training of complex tasks. *Human Factors*. **38**(2),pp.330–346.

Goffe, W.L. and Kauper, D. (2014) A Survey of Principles Instructors: Why Lecture Prevails. *The Journal of Economic Education*. **45**(4),pp.360–375.

Golany, B., Kaplan, E.H., Marmur, A. and Rothblum, U.G. (2009) Nature plays with dice–terrorists do not: Allocating resources to counter strategic versus probabilistic risks. *European Journal of Operational Research*. **192**(1),pp.198–208.

Goldblat, J. (1971) *The Problem of Chemical and Biological Warfare Volume IV: CB disarmament negotiations, 1920-1970*. Stockholm: SIPRI Stockholm International Peace Research Institute.

Goldstein, I.L. (1993) *Training in organizations: needs assessment, development, and evaluation* 3rd ed. Pacific Grove, CA: Brooks/Cole Pub. Co.

Gopher, D., Well, M. and Bareket, T. (1994) Transfer of Skill from a Computer Game Trainer to Flight. *Human Factors*. **36**(3),pp.387–405.

Gormley, A., Pollard, S., Rocks, S. and Black, E. (2011) *Guidelines for environmental risk assessment and management. Green Leaves III. Revised Departmental Guidance*. Richmond: Department for Environment, Food and Rural Affairs (DEFRA) and Collaborative Centre of Excellence in Understanding and Managing Natural and Environmental Risks of Cranfield University. [Accessed 18 August 2016]. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69450/pb13670-green-leaves-iii-1111071.pdf.

Gould, C., Folb, P. and Berold, R. (2002) *Project Coast: apartheid's chemical and biological warfare programme*. Geneva: United Nations.

Gould, C. and Hay, A. (2006) The South African Biological Weapons Program *In*: M. Wheelis, L. Rózsa and M. R. Dando, eds. *Deadly cultures: biological weapons since 1945*. Cambridge and London: Harvard Univ. Press, pp. 191–212.

Grainger, L. and Turegeldiyeva, D. (2015) Biorisk Management Training *In*: R. M. Salerno and J. M. Gaudioso, eds. *Laboratory biorisk management: biosafety and biosecurity*. Boca Raton London New York: CRC Press, Taylor & Francis Group, pp. 101–124.

Green, J.C. (2007) *Mixed Methods in Social Inquiry*. New York: Wiley.

Gressel, M. (2005) Hierarchy of controls and inherently safe design. American Industrial Hygiene Association. [Accessed 18 August 2016]. Available from: https://www.aiha.org/aihce05/handouts/rt219gressel_files/frame.htm.

Guillemin, J. (2011) *American Anthrax: Fear, Crime, and the Investigation of the Nation's Deadliest Bioterror Attack*. New York: Macmillan.

Guldenmund, F.W. (2000) The nature of safety culture: a review of theory and research. *Safety science*. **34**(1),pp.215–257.

Gustafson, K.L. and Branch, R.M. (2002) *Survey of instructional development models* Fourth edition. Syracuse, NY: ERIC Clearinghouse on Information & Technology.

Haak, D., HilleRisLambers, J., Broughton, E. and Freeman, S. (2011) Increased Structure and Active Learning Reduce the Achievement Gap in Introductory Biology. *Science*. **332**(6034),pp.1213–6.

Hadden, S.G. (1984) Introduction: Risk policy in American institutions *In*: S. G. Hadden, ed. *Risk analysis, institutions, and public policy*. Port Washington, NY: Associated Faculty Press, pp. 3–17.

Haimes, Y.Y., Kaplan, S. and Lambert, J.H. (2002) Risk Filtering, Ranking, and Management Framework Using Hierarchical Holographic Modeling. *Risk Analysis*. **22**(2),pp.383–397.

Hakim, C. (2000) *Research Design: Successful Designs for Social and Economic Research*. Routledge.

Halloun, I.A. and Hestenes, D. 1985. Common sense concepts about motion. *American journal of physics*. **53**(11),pp.1056–1065.

Halpern, D.F. and Hakel, M.D. (2003) Applying the science of learning to the university and beyond: Teaching for long-term retention and transfer. *Change: The Magazine of Higher Learning*. **35**(4),pp.36–41.

Hampel, J. (2006) Different concepts of risk – A challenge for risk communication. *International Journal of Medical Microbiology*. **296**,pp.5–10.

Handelsman, J., Miller, S. and Pfund, C. (2007) *Scientific Teaching*. W. H. Freeman.

Hansen, L. (2000) The Little Mermaid's Silent Security Dilemma and the Absence of Gender in the Copenhagen School. *Millennium - Journal of International Studies*. **29**(2),pp.285–306.

Hansson, S.O. and Aven, T. (2014) Is Risk Analysis Scientific? *Risk Analysis*. **34**(7),pp.1173–1183.

Harris, S. (1999) The Japanese Biological Warfare Programme: An Overview *In*: E. Geissler and J. E. von Courtland Moon, eds. *Biological and Toxin Weapons: Research, Development and Use from the Middle Ages to 1945*. SIPRI Chemical & Biological Warfare Studies. Oxford and New York: Oxford University Press, pp. 127–152.

Hattis, D. and Minkowitz, W.S. (1996) Risk evaluation: criteria arising from legal traditions and experience with quantitative risk assessment in the United States. *Environmental Toxicology and Pharmacology*. **2**,pp.103–109.

Hay, A. (2007) Multiple Uses of Chemicals: Clear Choices or Dodgy Deals? *Chemistry International, The News Magazine of the International Union of Pure and Applied Chemistry IUPAC*. **29**(6). [Accessed 8 August 2016]. Available from: https://www.iupac.org/publications/ci/2007/2906/pp2_2005-029-1-050.html.

Hay, A. and Mahaffy, P. (2013) Multiple Uses of Chemicals. *OPCW Today*. **2**(5),pp.23–24.

Hodell, C. (2011) *ISD from the ground up: a no-nonsense approach to instructional design* 3rd ed. Alexandria, VA: American Society for Training & Development.

Hohenemser, C., Kates, R.W. and Slovic, P. (1983) The nature of technological hazard. *Science*. **220**(4595),pp.378–384.

Hokstad, P. and Steiro, T. (2006) Overall strategy for risk evaluation and priority setting of risk regulations. *Reliability Engineering & System Safety*. **91**(1),pp.100–111.

Holstein, J.A. and Miller, G. (2006) *Reconsidering Social Constructionism: Debates in Social Problems Theory*. New Brunswich and London: Transaction Publishers.

House of Commons (2002) *The Biological Weapons Green Paper*. London: Foreign Affairs Commitee of the House of Commons.

Huysmans, J. (1995) Migrants as a Security Problem: Dangers of 'Securitizing' Societal Issues *In*: *Migration and European Integration: Dynamics of Inclusion and Exclusion*. London: Pinter, pp. 53–72.

IAEA (2010) International Nuclear Security Education Network (INSEN). *International Atomic Energy Agency*. [Online]. [Accessed 18 August 2016]. Available from: http://www-ns.iaea.org/security/workshops/insen-wshop.asp.

IAP (2014) *IAP Statement on Realising Global Potential in Synthetic Biology: Scientific Opportunities and Good Governance*. Trieste: IAP - the global network of science academies.

IAP (2005) *IAP Statement on Biosecurity*. Trieste: InterAcademy Panel. [Accessed 18 August 2016]. Available from: http://www.interacademies.net/File.aspx?id=5401.

IASB (2009) The IASB Code of Conduct for Best Practices in Gene Synthesis. *International Association of Synthetic Biology*. [Accessed 18 August 2016]. Available from: http://www.ia-sb.eu/tasks/sites/synthetic-biology/assets/File/pdf/iasb_code_of_conduct_final.pdf.

ICRC (2003) *Biotechnology, Weapons and Humanity. An informal meeting of government and independent experts Montreux, Switzerland / 23-24 September 2002. Summary Report*. Geneva: International Commitee of the Red Cross. [Accessed 21 August 2016]. Available from: https://www.icrc.org/eng/assets/files/other/montreux_report.pdf.

India (2015) *Intervention by India on Review of S&T Developments (BWC Meeting of Experts, 2015).* Geneva: Biological and Toxin Weapons Convention.

India (2005) *Indian Initiatives on Codes of Conduct for Scientists. Working Paper. BWC/MSP/2005/MX/WP.23*. Geneva: Biological and Toxin Weapons Convention.

INES (2013a) *INES Statement to the Meeting of Experts to the Biological and Toxin Weapons Convention, Geneva, August 2013*. Geneva: Biological and Toxin Weapons Convention.

INES (2013b) International Network of Engineers and Scientists for Global Responsibility. Mission Statement. *International Network of Engineers and Scientists for Global Responsibility*. [Accessed 18 July 2016]. Available from: http://www.inesglobal.com/mission-statement.phtml.

Iran (2008) *Statement by Mr. Reza Najafi, Director of Department for Disarmament and International Security, Ministry of Foreign Affairs of the Islamic Republic of Iran before the Meeting of Experts of the States Parties to the BWC. Geneva - 18 August 2008.* Geneva: Biological and Toxin Weapons Convention.

ISO (2015) *Quality management principles*. Geneva: International Organization for Standardization.

Isukapalli, S.., Lioy, P.J. and Georgopoulos, P.G. (2008) Mechanistic Modeling of Emergency Events: Assessing the Impact of Hypothetical Releases of Anthrax. *Risk Analysis*. **28**(3),pp.723–740.

Jabri, V. (2006) War, Security and the Liberal State. *Security Dialogue*. **37**(1),pp.47–64.

Jackson, R.J., Ramsay, A.J. and Christensen, C.D. (2001) Expression of mouse interleukin-4 by a recombinant ectromelia virus suppresses cytolytic lymphocyte responses and overcomes genetic resistance to mousepox. *Journal of Virology*. **75**(3),pp.1205–1210.

Japan (2013) *Preliminary views on the paper entitled 'We need to talk about compliance'. Working Paper. BWC/MSP/2013/MX/WP.18. 13 August 2013.* Geneva: Biological and Toxin Weapons Convention.

Japan (2008) *Oversight, Education, Awareness Raising, and Codes of Conduct for Preventing the Misuse of Bio-Science and Bio-Technology. Working Paper. BWC/MSP/2008/MX/WP.21*. Geneva: Biological and Toxin Weapons Convention.

Jasanoff, S. (1993) Bridging the two cultures of risk analysis. *Risk analysis*. **13**(2),pp.123–129.

Jensen, E. (2005) *Teaching with the brain in mind* 2nd ed. Alexandria, VA: Association for Supervision & Curriculum Development.

Jentsch, F. and Bowers, C. (1998) Evidence for the validity of PC-based simulations in studying aircrew coordination. *International Journal of Aviation Psychology*. **8**,pp.243–60.

Johnson, B. (2001) Toward a New Classification of Nonexperimental Quantitative Research. *Educational Researcher*. **30**(2),pp.3–13.

Johnson, J. (2012) Teaching Ethics to Science Students: Challenges and a Strategy *In*: B. Rappert, ed. *Education and Ethics in the Life Sciences*. Canberra: ANU E Press, pp. 197–213.

Jonkman, S.N., van Gelder, P.H.A.J.M. and Vrijling, J.K. (2003) An overview of quantitative risk measures for loss of life and economic damage. *Journal of Hazardous Materials*. **99**(1),pp.1–30.

Journal Editors and Authors Group (2003) Uncensored exchange of scientific results. *Proceedings of the National Academy of Sciences*. **100**(4),pp.1464–1464.

Jungermann, H. and Slovic, P. (1993) Charakteristika individueller Risikowahrnehmung *In*: W. Krohn and G. Krucken, eds. *Riskante Technologien: Reflexion und Regulation*. Frankfurt Am Main: Suhrkamp.

Kagan, E. (2001) Bioregulators as instruments of terror. *Clinics in Laboratory Medicine*. **21**(3),pp.607–618.

Kaplan, S. (1997) The words of risk analysis. *Risk analysis*. **17**(4),pp.407–417.

Kaplan, S. and Garrick, B.J. (1981) On the quantitative definition of risk. *Risk analysis*. **1**(1),pp.11–27.

Kasperson, R.E., Renn, O., Slovic, P., Brown, H.S., Emel, J., Goble, R., Kasperson, J.X. and Ratick, S. (1988) The social amplification of risk: A conceptual framework. *Risk analysis*. **8**(2),pp.177–187.

Kates, R.W. and Kasperson, J.X. (1983) Comparative risk analysis of technological hazards (a review). *Proceedings of the National Academy of Sciences*. **80**(22),pp.7027–7038.

Kaufman, D., Sauvé, L. and Ireland, A. (2007) New tools, new tricks? Evaluating games and simulations from multiple perspectives. *Organizing and Learning Through Gaming and Simulation: Proceedings of Isaga*.,pp.167–174.

Kaufman, S.G. and Berkelman, R. (2007) Biosafety ‘Behavioral-Based’ Training for High Biocontainment Laboratories: Bringing Theory into Practice for Biosafety Training. *Applied Biosafety*. **12**(3),pp.178–184.

Keeney, G.L. and von Winterfeldt, D. (2010) Identifying and Structuring the Objectives of Terrorists: Identifying and Structuring the Objectives of Terrorists. *Risk Analysis*. **30**(12),pp.1803–1816.

Kelle, A. (2007a) Securitization of International Public Health - Implications for Global Health Governance and the Biological Weapons Prohibition Regime. *Global Governance*. **13**(2),pp.217–235.

Kelle, A. (2007b) *Synthetic Biology and Biosecurity Awareness in Europe. Bradford Science and Technology Report.* Bradford: Department of Peace Studies, University of Bradford.

Kelle, A. (2005a) Bioterrorism and the Securitization of Public Health in the United States of America - Implications for Public Health and Biological Weapons Arms Control. *Bradford Regime Review Paper*. **2**.

Kelle, A. (2005b) Discourses on the Securitization of Public Health - A Survey of Four Countries. *Bradford Regime Review Paper*. **3**.

Kelle, A. (2005c) Securitization of International Public Health. *Bradford Regime Review Paper No. 2.* **1**.

Kenya (2014) *Statement by Ms. Roselida Owuor, Senior Science Secretary/Alternate National Contact Person for BTWC, National Commission for Science, Technology and Innovation, Head of Kenya Delegation at the Biological and Toxin Weapons Convention Meeting of Experts, Palais des Nations, 4-8 August 2014, Geneva, Switzerland. 4 August 2014*. Geneva: Biological and Toxin Weapons Convention.

Kenya (2008) *Statement by H.E. Mr. Philip Richard O. Owade, Ambassador/Deputy Permanent Representative of Kenya to the United Nations in Geneva, at the Meeting of States Parties to the Biological and Toxin Weapons Convention, December 2, 2008*. Geneva: Biological and Toxin Weapons Convention.

Kidd, J.R. (1974) *How Adults Learn*. Cambridge: Cambridge Book Co.

Kirkpatrick, D.L. (1996) Great ideas revisited. *Training and Development*. **50**(1),pp.54–59.

Kirkpatrick, D.L. (1979) Techniques for evaluating training programs. *Training and Development*. **June 1979**,pp.178–192.

Kirkpatrick, D.L. (1976) Evaluation of training *In*: R. L. Craig, ed. *Training and development handbook - A guide to human resource development*. New York: McGraw-Hill, p. 859.

Kirkpatrick, D.L. and Kirkpatrick, J.D. (2007) *Implementing the Four Levels: A Practical Guide for Effective Evaluation of Training Programs*. Berrett-Koehler Publishers.

Kirkpatrick, D.L. and Kirkpatrick, J. (2006) *Evaluating training programs* 3rd ed. San Francisco, CA: Berrett-Koehler Publishers.

Klaassen, C.D., Casarett, L.J. and Doull, J. (eds.). (2013) *Casarett and Doull's toxicology: the basic science of poisons* 8th ed. New York: McGraw-Hill Education.

Klinke, A. and Renn, O. (2002) A New Approach to Risk Evaluation and Management: Risk-Based, Precaution-Based and Discourse-Based Strategies. *Risk Analysis*. **22**(6),pp.1071–1094.

Klinke, A. and Renn, O. (2001) Precautionary principle and discursive strategies: classifying and managing risks. *Journal of Risk Research*. **4**(2),pp.159–173.

Knight-Jones, T.J.D. and Rushton, J. (2013) The economic impacts of foot and mouth disease – What are they, how big are they and where do they occur? *Preventive Veterinary Medicine*. **112**(3-4),pp.161–173.

Knowles, M.S. (1984) *The Adult Learner: A Neglected Species* 3rd ed. Houston, TX: Gulf Publishing.

Knox, A.B. (1977) *Adult development and learning*. San Francisco: Jossey-Bass.

Koblentz, G.D. (2009) *Living Weapons*. Ithaca, NY: Cornell University Press.

Kolb, D.A. (1984) *Experiential learning: experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice Hall.

Kolb, D.A. (1976) *Learning styles inventory. Technical Manual.* Boston, MA: McBer & Co.

Kolb, D.A. (1973) *On management and the learning process*. Cambridge, MA: Massachussetts Institute of Technology.

Kolb, D.A. (1971) *Individual learning styles and the learning process*. Cambridge, MA: Massachussetts Institute of Technology.

Kolb, A.Y. and Kolb, D.A. (2005) Learning styles and learning spaces: Enhancing experiential learning in higher education. *Academy of management learning & education*. **4**(2),pp.193–212.

Kolb, D.A., Boyatzis, R.E. and Mainemelis, C. (2001) Experiential learning theory: Previous research and new directions. *Perspectives on thinking, learning, and cognitive styles*. **1**,pp.227–247.

Kontoghiorghes, C. (2004) Reconceptualizing the learning transfer conceptual framework: Empirical validation of a new systemic model. *International journal of training and development*. **8**(3),pp.210–221.

Koo, D. and Miner, K. (2010) Outcome-Based Workforce Development and Education in Public Health. *Annual Review of Public Health*. **31**(1),pp.253–269.

Kraiger, K., Ford, J.K. and Salas, E. (1993) Application of cognitive, skill-based, and affective theories of learning outcomes to new methods of training evaluation. *Journal of applied psychology*. **78**(2),p.311.

Krathwohl, D.R. (2002) A revision of Bloom's taxonomy: An overview. *Theory into practice*. **41**(4),pp.212–218.

Kuhlau, F., Höglund, A.T., Evers, K. and Eriksson, S. (2011) A Precautionary Principle for Dual Use Research in the Life Sciences. *Bioethics*. **25**(1),pp.1–8.

Kunreuther, H. (2002) Risk analysis and risk management in an uncertain world. *Risk analysis*. **22**(4),pp.655–664.

Kysil, O. (2012) Awareness Raising / Education on Biosafety / Biosecurity in Ukraine *In*: *Recent Developments in Education, Side Event to the 2012 BTWC Meeting of Experts of the States Parties to the Biological and Toxin Weapons Convention*. Geneva.

Labanca, N. (2000) Key Points in the History of Biological Warfare. *In*: *Proceedings of the Conference on Biosecurity and Bioterrorism, Rome, September 2000*. Como: Landau Network Centro Volta, pp. 83–104.

Labodová, A. (2004) Implementing integrated management systems using a risk analysis based approach. *Journal of Cleaner Production*. **12**(6),pp.571–580.

Latour, B. (2005) Biopotere e vita pubblica *In*: *Biopolitica. Storia e attualità di un concetto*. Verona: Ombre Corte.

Latour, B. and Lagomarsino, G. (2009) *Non siamo mai stati moderni*. Milano: Eléuthera.

Leboeuf, A. and Broughton, E. (2008) *Securitization of Health and Environmental Issues: Process and Effects. A research outline.* Paris: Institut français des relations internationales.

Lebow, D. (1993) Constructivist values for instructional systems design: Five principles toward a new mindset. *Educational technology research and development*. **41**(3),pp.4–16.

Lee, J.E.C. and Lemyre, L. (2009) A Social-Cognitive Perspective of Terrorism Risk Perception and Individual Response in Canada. *Risk Analysis*. **29**(9),pp.1265–1280.

Lee, J.M. (2015) Offsetting or Enhancing Behavior: An Empirical Analysis of Motorcycle Helmet Safety Legislation. *Risk Analysis*. **35**(10),pp.1820–1836.

Leitenberg, M. (2005) Assessing the Biological Weapons and Bioterrorism Threat. [Accessed 8 October 2016]. Available from: http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA442204.

Leitenberg, M., Zilinskas, R.A. and Kuhn, J.H. (2012) *The Soviet Biological Weapons Program*. Cambridge, MA: Harvard Univ. Press.

Lempinen, E.W. (2011) FBI, AAAS Collaborate on Ambitious Outreach to Biotech Researchers and DIY Biologists. *American Association for the Advancement of Science*. [Accessed 4 August 2016]. Available from: http://www.aaas.org/news/fbi-aaas-collaborate-ambitious-outreach-biotech-researchers-and-diy-biologists.

Lennane, R. (2011) Verification for the BTWC: if not the protocol, then what? *Disarmament Forum*. **1**,pp.39–50.

Lentzos, F. and Sims, N.A. (2008) *Statement to the Biological and Toxin Weapons Convention Meeting of Experts. NGO Statements (London School of Economics and Political Science). 18 August 2008*. Geneva: Biological and Toxin Weapons Convention.

Lepick, O. (1999) French Activities Related to Biological Warfare, 1919-45 *In*: E. Geissler and J. E. von Courtland Moon, eds. *Biological and Toxin Weapons: Research, Development and Use from the Middle Ages to 1945*. SIPRI Chemical & Biological Warfare Studies. Oxford and New York: Oxford University Press, pp. 70–90.

Lepick, O. (2006) The French Biological Weapons Program *In*: M. Wheelis, L. Rózsa and M. R. Dando, eds. *Deadly cultures: biological weapons since 1945*. Harvard University Press, pp. 108–131.

Letherby, G., Scott, J. and Williams, M. (2012) *Objectivity and Subjectivity in Social Research*. Thousands Oaks, London and New Delhi: SAGE Publications.

Leung, M., Lambert, J.H. and Mosenthal, A. (2004) A risk- based approach to setting priorities in protecting bridges against terrorist attacks. *Risk Analysis*. **24**(4),pp.963–984.

Li, H., Apostolakis, G.E., Gifun, J., VanSchalkwyk, W., Leite, S. and Barber, D. (2009) Ranking the Risks from Multiple Hazards in a Small Community. *Risk Analysis*. **29**(3),pp.438–456.

Likert, R. (1958) Measuring organizational performance. *Harvard business review*. **36**(2),pp.41–50.

Lind, N. (2002) Social and Economic Criteria of Acceptable Risk. *Reliability Engineering and System Safety*. **78**,pp.21–25.

Linkov, I., Satterstrom, F.K., Steevens, J., Ferguson, E. and Pleus, R.C. (2007) Multi-criteria decision analysis and environmental risk assessment for nanomaterials. *Journal of Nanoparticle Research*. **9**(4),pp.543–554.

Littlewood, J. (2004) *Managing the Biological Weapons Problem*. Weapons of Mass Destruction Commission (WMDC). [Accessed 4 August 2016]. Available from: http://www.blixassociates.com/wp-content/uploads/2011/03/no14.pdf.

Loewenstein, G.F., Weber, E.U., Hsee, C.K. and Welch, N. (2001) Risk as feelings. *Psychological bulletin*. **127**(2),p.267.

Lupton, D. (1999) *Risk*. London and New York: Routledge.

Mancini, G.M. (2015) Biological Weapons and Biowarfare: Historical Perspectives and Challenges for the Twenty- First Century *In*: P. Foradori, ed. *Still the century of overkill? strengthening the control of weapons of mass destruction*. Non-proliferation and disarmament studies. Baden-Baden: Nomos, pp. 119–140.

Mancini, G.M. (2012a) European Biosecurity Awareness Raising Network *In*: *IWG-Global Partnership Meeting, Miami, 16 April 2012*. Miami: Landau Network - Centro Volta.

Mancini, G.M. (2012b) The European Biosecurity Awareness Raising Network *In*: *The Intersessional Process, Science and Education. Side Event to the Meeting of States Parties to the Biological and Toxin Weapons Convention*. Geneva: Landau Network - Centro Volta.

Mancini, G.M. and Fasani, A. (2012a) Experiences in Promoting Awareness on Biosecurity and Dual Use Issues in European Universities *In*: *Responsible Conduct of Research for Scientists and Engineers and COST Twin International Meeting*. Bradford: University of Bradford.

Mancini, G.M. and Fasani, A. (2012b) Experiences in Promoting Awareness on Biosecurity and Dual Use Issues in European Universities *In*: J. F. Sture, ed. *Yearbook of Biosecurity Education 2012*. Bradford: University of Bradford, pp. 76–86.

Mancini, G.M. and Revill, J. (2009) *Promoting Sustainable Education and Awareness Raising on Biosecurity and Dual Use*. Como and Bradford: Landau Network Centro Volta and the University of Bradford.

Mancini, G.M. and Revill, J. (2008) *Fostering the Biosecurity Norm. Biosecurity Education for the Next Generation of Life Scientists*. Como and Bradford: Landau Network Centro Volta and the University of Bradford.

Mancini, G.M., Walther, G. and Dando, M. (2012) Dual use and military applications of neuroscience *In*: *Neurosciences & Biotechnologies, Avancées en Recherche et Perspectives. 21 May 2012*. Beyrut: Faculté de Médecine et des Sciences Médicales en collaboration avec le Centre Supérieur de la Recherche à l'USEK.

Margalho, A. (2009) Cientistas alertados para perigos. *Diàrio de Coimbra*. 24 November 2009,p.4.

Marris, C., Langford, I.H. and O'Riordan, T. (1998) A Quantitative Test of the Cultural Theory of Risk Perceptions: Comparison with the Psychometric Paradigm. *Risk Analysis*. **18**(5),pp.635–647.

Mason, J. (2006) *Six Strategies for Mixing Methods and Linking Data in Social Research*. ESRC National Centre for Research Methods. [Accessed 8 March 2016]. Available from: http://eprints.ncrm.ac.uk/482/1/0406_six%2520strategies%2520for%2520mixing%2520methods.pdf.

McCombs, B.L. (1986) ERIC/ECTJ Annual Review Paper: The Instructional Systems Development (ISD) Model: A Review of Those Factors Critical to Its Successful Implementation. *Educational Communication and Technology*.,pp.67–81.

McGill, W.L., Ayyub, B.M. and Kaminskiy, M. (2007) Risk analysis for critical asset protection. *Risk Analysis*. **27**(5),pp.1265–1281.

McLeish, C. and Nightingale, P. (2007) Biosecurity, bioterrorism and the governance of science: The increasing convergence of science and security policy. *Research Policy*. **36**(10),pp.1635–1654.

Meselson, M. (2000) Averting the hostile exploitation of biotechnology. *The CB Conventions Bulletin*. **38**(June 2000),pp.16–19.

Meselson, M., Guillemin, J., Hugh-Jones, M. and Langmuir, A. (1994) The Sverdlovsk anthrax outbreak of 1979. *Science*. **266**,pp.1202–1208.

Michael, J. (2006) Where's the evidence that active learning works? *Advances in Physiology Education*. **30**,pp.159–167.

Mierzejewski, J.W. and van Courtland Moon, J.E. (1999) Poland and Biological Weapons *In*: E. Geissler and J. E. von Courtland Moon, eds. *Biological and Toxin Weapons: Research, Development and Use from the Middle Ages to 1945*. SIPRI Chemical & Biological Warfare Studies. Oxford and New York: Oxford University Press, pp. 63–69.

Miles, M.B. and Huberman, A.M. (1984) *Qualitative data analysis: a sourcebook of new methods*. Thousands Oaks, London and New Delhi: SAGE Publications.

Miller, S. and Selgelid, M.J. (2007) Ethical and Philosophical Consideration of the Dual-use Dilemma in the Biological Sciences. *Science and Engineering Ethics*. **13**(4),pp.523–580.

Millett, P. (2010) Building a Regime to Secure Biology in the Twenty-First Century *In*: *Improving Implementation of the Biological Weapons Convention.*

The Intersessional Process. New York and Geneva: United Nations Disarmament Institute, pp. 59–64.

Mills, S. (2003) *Michel Foucault*. New York: Routledge.

Minehata, M. (2010) *An Investigation of Biosecurity Education for Life Scientists in the Asia-Pacific Region*. Bradford: University of Exeter and University of Bradford.

Minehata, M. and Friedman, D. (2009) *Biosecurity Education in Israeli Research Universities: Survey Report*. Tel Aviv and Bradford: Institute for National Security Studies and Bradford Disarmament Research Centre.

Minehata, M. and Shinomiya, N. (2010) Chapter 5: Japan: Obstacles, Lessons and Future *In*: B. Rappert, ed. *Education and Ethics in the Life Sciences*. Canberra: ANU E Press.

Minehata, M. and Shinomiya, N. (2009) *Biosecurity Education: Enhancing Ethics, Securing Life and Promoting Science: Dual Use Education in Life Science Degree Courses at Universities in Japan*. Saitama and Bradford: National Defence Medical College and University of Bradford.

Moen, R. and Norman, C. (2006) *Evolution of the PDCA cycle*. Georgetown, TX: Profound Knowledge Products Inc. [Accessed 17 July 2016]. Available from: http://pkpinc.com/files/NA01_Moen_Norman_fullpaper.pdf.

Mohtadi, H. (2006) A global chronology of incidents of chemical, biological, radioactive and nuclear attacks: 1950-2005. [Accessed 4 August 2016]. Available from: http://www.ncfpd.umn.edu/Ncfpd/assets/File/pdf/GlobalChron.pdf.

Molenda, M. (2003) In search of the elusive ADDIE model. *www.ispi.org*. **3**(May/June 2003),pp.34–36.

Morgan, P.M. (1999) *Liberalist and Realist Security Studies at 2000*. London and New York: Routledge.

Morgan, R.B. and Casper, W.J. (2000) Examining the factor structure of participant reactions to training: A multidimensional approach. *Human Resource Development Quarterly*. **11**(3),p.301.

Morocco (2008) *Statement, Biological Weapons Convention - 2008 Meeting of States Parties, Geneva, 1-5 December 2008, Monday, 1 December.* Geneva: Biological and Toxin Weapons Convention.

National Research Council (2014) *Emerging and readily available technologies and national security: a framework for addressing ethical, legal, and societal issues*. Washington, DC: National Academies Press.

National Research Council 2013. *Developing Capacities for Teaching Responsible Science in the MENA Region: Refashioning Scientific Dialogue*. Washington, DC: National Academies Press.

National Research Council (2012) *Research in the Life Sciences with Dual Use Potential: An International Faculty Development Project on Education About the Responsible Conduct of Science*. Washington, DC: National Academies Press.

National Research Council (2011a) *Life Sciences and Related Fields: Trends Relevant to the Biological Weapons Convention*. Washington, DC: The National Academies Press.

National Research Council (2011b) *U.S. and International Perspectives on Global Science Policy and Science Diplomacy: Report of a Workshop*. The National Academies Press.

National Research Council (2010) *Challenges and Opportunities for Education About Dual Use Issues in the Life Sciences*. Washington, DC: National Academies Press.

National Research Council (2009a) *Global Security Engagement: A New Model for Cooperative Threat Reduction*. Washington, DC: National Academies Press.

National Research Council (2009b) *On Being a Scientist: A Guide to Responsible Conduct in Research: Third Edition*. Washington, DC: National Academies Press.

National Research Council (2009c) *Opportunities in neuroscience for future army applications*. Washington, DC: National Academies Press.

National Research Council (2008) *Department of Homeland Security Bioterrorism Risk Assessment: A Call for Change*. Washington, DC: National Academies Press.

National Research Council (2006) *Globalization, Biosecurity, and the Future of the Life Sciences*. Washington, DC: National Academies Press.

National Research Council (2004) *Biotechnology Research in an Age of Terrorism*. Washington, DC: National Academies Press.

National Research Council (2003a) *Bio 2010: transforming undergraduate education for future research biologists*. Washington, DC: National Academies Press.

National Research Council (2003b) *Evaluating and improving undergraduate teaching in science, technology, engineering, and mathematics*. Washington, DC: National Academies Press.

National Research Council (2000) *How People Learn: Brain, Mind, Experience, and School: Expanded Edition*. Washington, DC: The National Academies Press.

National Research Council and American Association for the Advancement of Science. (2009) *A survey of attitudes and actions on dual use research in the life sciences: a collaborative effort of the National Research Council and the American Association for the Advancement of Science*. Washington, DC: National Academies Press.

Nesbit, J.C. and Hunka, S. (1987) A method for sequencing instructional objectives which minimizes memory load. *Instructional Science*. **16**(2),pp.137–150.

Netherlands (2008) *Development of a Code of Conduct on Biosecurity. Working Paper. BWC/MSP/2008/MX/WP.8*. Geneva: Biological and Toxin Weapons Convention.

Netherlands (2015) *Statement on Science and Technology, 12-8-2015. Ms. Ayse Aydin, Senior Policy Adviser, Ministry of Foreign Affairs of the Kingdom of the Netherlands. 2015 Meeting of Experts of the States Parties of the Biological and Toxin Weapons Convention.* Geneva: Biological and Toxin Weapons Convention.

Neuman, W. (1997) Social research methods: qualitative and quantitative approaches. Needham Heights, MA: Allyn & Bacon.

New Scientist (2003) For Whose Eyes Only. Editorial. *New Scientist*. Available from: http://www.newscientist.com/article/mg17723780.100-for-whose-eyes-only.html.

New Zealand (2016) Biosecurity. [Accessed 8 August 2016]. Available from: http://www.mpi.govt.nz/law-and-policy/legal-overviews/biosecurity/.

Nigeria (2008) *Biological Weapons Convention: Meeting of Experts. National, Regional and International Measures to Improve Biosafety and Biosecurity, including Laboratory Safety and Security of Pathogens. Capacity Building. 20 August 2008.* Geneva: Biological and Toxin Weapons Convention.

Novossiolova, T. (2016) *Biological Security Education Handbook: The Power of Team-Based Learning*. Bradford: University of Bradford.

Novossiolova, T. (2015) *Statement by Ms. Tatyana Novossiolova on behalf of the International Association of Biosafety Associations and the Bradford Disarmament Research Centre, UK to the Meeting of States Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction. 14 December 2015.* Geneva: Biological and Toxin Weapons Convention.

Novossiolova, T. (2013) *Statement by Ms. Tatyana Novossiolova on behalf of Landau Network Centro Volta, Italy and University of Bradford, UK to the Meeting of Experts to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction. 12 August 2013.* Geneva: Biological and Toxin Weapons Convention.

Novossiolova, T., Mancini, G.M. and Dando, M.R. (2013) Effective and Sustainable Biosecurity Education for Those in the Life Sciences: the Benefits of Active Learning. *Bradford Briefing Papers on Strenghtening the Biological Weapons Convention, Third Series*. **7**(Third Series).

Novossiolova, T. and Pearson, G.S. (2012) Biosecurity Education for the Life Sciences: Nuclear Security Education Experience as a Model. *Bradford Briefing Papers on Strenghtening the Biological Weapons Convention, Third Series*. **3**(Third Series).

NSABB (2007) Proposed framework for the oversight of dual use life science research: strategies for minimizing the potential misuse of research information. Available from:

http://osp.od.nih.gov/sites/default/files/biosecurity_PDF_Framework%20for%20transmittal%200807_Sept07.pdf.

OECD (2007) *OECD Best Practice Guidelines for Biological Resource Centres*. Paris: Organization for Economic Cooperation and Development Publishing.

OECD (2001) *Biological Resource Centres Underpinning the Future of Life Sciences and Biotechnology*. Paris: Organization for Economic Cooperation and Development Publishing.

OIE (2011a) *Bioterrorism. Fact sheet*. Paris: World Organisation for Animal Health. [Accessed 8 August 2016]. Available from: http://www.oie.int/fileadmin/Home/eng/Current_Scientific_Issues/docs/pdf/BIOTE_EN_FS%20.pdf.

OIE (2011b) *World Organisation for Animal Health (OIE) opening statement Biologic and Toxin Weapons Convention, Seventh Review Conference*. Geneva: World Organisation for Animal Health.

Onuf, N. (1998) Constructivism: A User's Manual *In*: V. Kubálková, N. Onuf and P. Kowert, eds. *International Relations in a Constructed World*. Armonk, NY: M.E. Sharper, pp. 58–78.

Onuf, N. (1989) *World of Our Making*. Columbia: University of South Carolina Press.

OPCW (2013) *Report of the Second Meeting of the SAB Temporary Working Group on Education and Outreach in Science and Technology Relevant to the Chemical Weapons Convention*. Organisation for the Prohibition of Chemical Weapons. [Accessed 8 August 2016]. Available from: https://www.opcw.org/fileadmin/OPCW/SAB/en/sab-20-wp01_e_.pdf.

OSHA (2008) Hazard Prevention and Control. Safety & Health Management System eTool. *Occupational Safety and Health Administration*. [Accessed 18 August 2016]. Available from: https://www.osha.gov/SLTC/etools/safetyhealth/comp3.html.

Pakistan (2008a) *Perspective on Oversight, Codes of Conduct Education and Awareness Raising. Working Paper. BWC/MSP/2003/WP.5. 5 December 2008.* Geneva: Biological and Toxin Weapons Convention.

Pakistan (2008b) *Statement by Ambassador Masood Khan, Permanent Representative of Pakistan, General Debate at 2008 BWC Experts Meeting. Geneva, 18 August 2008.* Geneva: Biological and Toxin Weapons Convention.

Parnell, G.S., Smith, C.M. and Moxley, F.I. (2010) Intelligent Adversary Risk Analysis: A Bioterrorism Risk Management Model. *Risk Analysis*. **30**(1),pp.32–48.

Paté-Cornell, E. and Guikema, S. (2002) Probabilistic modeling of terrorist threats: A systems analysis approach to setting priorities among countermeasures. *Military Operations Research*. **7**(4),pp.5–23.

Patel, V., Yoskowitz, N. and Arocha, J. (2009) Towards effective evaluation and reform in medical education: a cognitive and learning sciences perspective. *Advances in Health Sciences Education*. **14**(5),pp.791–812.

Pearson, G.S. (1993) Prospects for chemical and biological arms control: The web of deterrence. *Washington Quarterly*. **16**,pp.145–162.

Pearson, G.S. (1990) The CBW Spectrum. *The ASA Newsletter*. **90**,pp.1, 7–8.

Pearson, G.S. (2006) The Iraqi Biological Weapons Program *In*: M. Wheelis, L. Rózsa and M. R. Dando, eds. *Deadly cultures: biological weapons since 1945*. Cambridge and London: Harvard Univ. Press, pp. 169–190.

Pereira, R. (2008) Processes of Securitization of Infectious Diseases and Western Hegemonic Power: A Historical-Political Analysis. *Global Health Governance*. **2**(1),pp.1–15.

Petro, J.B., Plasse, T.R. and McNulty, J.A. (2003) Biotechnology: impact on biological warfare and biodefense. *Biosecurity and Bioterrorism: Biodefense Strategy, Practice and Science*. **1(3)**,pp.161–168.

Phillips, D.C. (2000) An opinionated account of the constructivist landscape *In*: D. C. Phillips, ed. *Constructivism in education: Opinions and second opinions on controversial issues*. Chicago: National Society for the Study of Education, pp. 1–16.

Poland (2012) *The crucial role of life scientists in the effective implementation of the BTWC. Working Paper. BWC/MSP/2012/WP.2. 22 November 2012.* Geneva: Biological and Toxin Weapons Convention.

Potter, J. and Wetherell, M. (1987) *Discourse and social psychology: Beyond attitudes and behaviour*. Thousands Oaks, London and New Delhi: SAGE Publications.

Praslova, L. (2010) Adaptation of Kirkpatrick's four level model of training criteria to assessment of learning outcomes and program evaluation in Higher Education. *Educational Assessment, Evaluation and Accountability*. **22**(3),pp.215–225.

Prawat, R.S. and Floden, R.E. (1994) Philosophical perspectives on constructivist views of learing. *Educational Psychology*. **29**(1),pp.37–48.

Prince, M. (2004) Does active learning work? A review of the research. *Journal of Engineering Education*. **93**(3),pp.223–231.

Pugwash (2013) About Pugwash Conferences on Science and World Affairs. *pugwash.org*. [Accessed 5 August 2016]. Available from: http://www.pugwash.org/about.htm.

QAU (2014) Courses. *Department of Bio Technology of Quaid-i-Azam University, Islamabad*. [Accessed 20 August 2016]. Available from: http://bit.qau.edu.pk/coursesgeo.php.

Rappert, B. (2010) Introduction: Education as... *In*: B. Rappert, ed. *Education and Ethics in the Life Sciences*. Canberra: ANU E Press, pp. 3–21.

Rappert, B. (2009) *Experimental secrets*. Lanham and Plymouth: University Press of America.

Rappert, B. (2008) *Meeting of Experts of the States Parties to the Biological and Toxin Weapons Convention. 18 to 22 August 2008. Statement by Dr. Brian Rappert, Department of Sociology & Philosophy; University of Exeter, United Kingdom.* Geneva: Biological and Toxin Weapons Convention.

Rappert, B. (2007a) *Biotechnology, security and the search for limits*. Basingstoke and New York: Palgrave Macmillan.

Rappert, B. (2007b) Codes of conduct and biological weapons: an in-process assessment. *Biosecurity and Bioterrorism: Biodefense Strategy …*. **5**(2),pp.1–10.

Rappert, B. (2007c) Education for the Life Sciences: Choices and Challenges *In*: *A Web of Prevention: "Biological Weapons, Life Sciences and the Governance of Research*. London: Routledge, pp. 51–66.

Rappert, B. (2004) *Towards a Life Science Code: Countering the Threats from Biological Weapons*. Bradford: Department of Peace Studies, University of Bradford.

Rappert, B., Chevier, M. and Dando, M.R. (2006) In-depth Implementation of the BTWC: Education and Outreach. *Bradford Review Conference Paper*. **18**.

Rappert, B., Dando, M.R. and Chevier, M. (2006) The Life Sciences, Biosecurity, and Dual Use Research. Educational Resources. *University of Exeter*. [Accessed 18 August 2016]. Available from: http://projects.exeter.ac.uk/codesofconduct/BiosecuritySeminar/.

Reader, T.W., Noort, M.C., Shorrock, S. and Kirwan, B. (2015) Safety sans Frontières: An International Safety Culture Model: An International Safety Culture Model. *Risk Analysis*. **35**(5),pp.770–789.

Ree, M.J., Carretta, T.R. and Teachout, M.S. (1995) Role of ability and prior knowledge in complex training performance. *Journal of Applied Psychology*. **80**(6),pp.721–730.

Renn, O. (2006) *Risk Governance. Towards an Integrative Approach. White Paper No. 1*. Geneva: International Risk Governance Council.

Renn, O. (1998) Three decades of risk research: accomplishments and new challenges. *Journal of risk research*. **1**(1),pp.49–71.

Republic of Korea (2008) *Compendium of National Activities. Republic of Korea. Oversight, Education, Awareness Raising and Adoption and/or Development of Codes of Conduct for Scientists*. Geneva: Biological and Toxin Weapons Convention.

Reus-Smit, C. (2005) Constructivism *In*: S. Burchill and A. Linklater, eds. *Theories of International Relations*. Basingstoke and New York: Palgrave Macmillan, pp. 188–212.

Revill, J. (2009) *Biosecurity and Bioethics Education: A Case Study of the UK Context*. Bradford: University of Bradford.

Revill, J., Candia Carnevali, M., Fosberg, A., Shinwari, Z.K., Rath, J. and Mancini, G.M. (2012) Lessons learned from implementing education on dual-use in Austria, Italy, Pakistan and Sweden. *Medicine, Conflict and Survival*. **28**(1),pp.31–44.

Revill, J. and Dando, M.R. (2006) A Hippocratic Oath for life scientists: A Hippocratic-style oath in the life sciences could help to educate researchers about the dangers of dual-use research. *EMBO reports*. **7**,pp.S55–S60.

Revill, J. and Mancini, G.M. (2010) Implementing and Measuring the Efficacy of Biosecurity and Dual Use Education *In*: B. Rappert, ed. *Education and Ethics in the Life Sciences*. Canberra: ANU E Press, pp. 165–178.

Ricci, J. (2009) The Securitisation of Swine Flu? *e-ir.info*. [Online]. [Accessed 5 February 2013]. Available from: http://www.e-ir.info/2009/04/30/swine-flu-and-securitisation/.

Ricci, K.E., Salas, E. and Cannon-Bowers, J.A. (1996) Do computer-based games facilitate knowledge acquisition and retention? *Military Psychology*. **8**(4),pp.295–307.

Ripandelli, D. (2005) Building Blocks for a Code of Conduct for Scientists, in Relaton to the Safe and Ethical Use of Biological Sciences. Presentation to the Biological and Toxin Weapons Convention Meeting of Experts of States Parties, 13 June 2005.

Robson, C. (2011) *Real World Research* 3rd ed. Chichester: John Wiley & Sons.

Rodham Clinton, H. (2011) Remarks at the 7th Biological and Toxin Weapons Convention Review Conference. [Accessed 8 August 2016]. Available from: http://www.state.gov/secretary/20092013clinton/rm/2011/12/178409.htm.

Rosati, P., Dean, R.K. and Rodman, S.M. (1988) A study of the relationship between students' learning styles and instructors' lecture styles. *IEEE transactions on education*. **31**(3),pp.208–212.

Rosenberg, B.H. (2003) Defending Against Biodefense: The Need for Limits. *Disarmament Diplomacy*. **30**(February/March 2003). Available from: http://www.fas.org/bwc/papers/defending.pdf.

Roster, C.A., Rogers, R.D., Albaum, G. and Klein, D. (2004) A comparison of response characteristics from web and telephone surveys. *International Journal of Market Research*. **46**(3),pp.359–73.

Rothschild, E. (1995) What is Security? *Daedalus*. **124**(3),pp.53–98.

Royal Dutch Academy of Sciences (2007) *A Code of Conduct for Biosecurity: Report by the Biosecurity Working Group*. Amsterdam: Royal Netherlands Academy of Arts and Sciences.

Royal Society (2012) *Brain waves module 3 Neuroscience, conflict and security*. London: Royal Society. [Accessed 9 August 2016]. Available from: http://royalsociety.org/policy/projects/brain-waves/conflict-security/.

Royal Society (2010) *New frontiers in science diplomacy.* London: Royal Society.

Royal Society (2009) *New approaches to biological risk assessment*. London: Royal Society.

Ruggie, J.G. (1998) What makes the world hang together? Neo-utilitarianism and the social constructivist challenge. *International organization*. **52**(04),pp.855–885.

Ruiz-Primo, M.A., Briggs, D., Iverson, H., Talbot, R. and Shepard, L.A. (2011) Impact of undergraduate science course innovation on learning. *Science*. **331**,pp.1269–1270.

Russian Federation (2008) *Statement by H.E. Ambassador Valery Loschchinin, Head of the delegation of the Russian Federation, Permanent Representative of the Russian Federation, at the Meeting of Experts of States Parties to the Biological and Toxin Weapons Convention, Geneva, 18 August 2008.* Geneva: Biological and Toxin Weapons Convention.

Russian Federation (2005a) *Answers to the Questions Regarding Codes of Conduct for Scientists Majoring in Biological Sciences. Working Paper. BWC/MSP/2005/MX/WP.19*. Geneva: Biological and Toxin Weapons Convention.

Russian Federation (2005b) *Some Reflections on the Ethic Norms and Codes of Conduct for Scientists Majoring in Biosciences. Working Paper. BWC/MSP/2005/MX/WP.18*. Geneva: Biological and Toxin Weapons Convention.

Salas, E. and Cannon-Bowers, J.A. (2001) The science of training: A decade of progress. *Annual review of psychology*. **52**(1),pp.471–499.

Salerno, R.M. and Gaudioso, J. (2007) *Laboratory Biosecurity Handbook*. Boca Raton, FL: Taylor & Francis.

Salerno, R.M., Gaudioso, J., Frerichs, R.L. and Estes, D. (2004) A BW risk assessment: Historical and technical perspectives. *The Nonproliferation Review*. **11**(3),pp.25–55.

Sandell, L. (2012) Ethical Science. *Blandet. Uppsala naturvetarstudenters tidning*. (3/2012),p.8.

Sandia National Laboratories (2014a) *IBTR Factsheet. SAND2014-19405 M*. Albuquerque, NM: Sandia National Laboratories.

Sandia National Laboratories (2014b) *Laboratory Biosafety and Biosecurity Risk Assessment Technical Guidance Document. SAND2014-15939R*. Albuquerque, NM: Sandia National Laboratories. Available from: http://prod.sandia.gov/techlib/access-control.cgi/2014/1415939r.pdf.

Sandia National Laboratories (2013) Global Biorisk Management Curriculum (GBRMC). *Sandia National Laboratories*. [Accessed 18 August 2016]. Available from: http://biosecurity.sandia.gov/gbrmc/.

Sarantakos, S. (1999) *Social research* 2nd ed. Basingstoke: Macmillan.

Saris, W.E. and Gallhofer, I.N. (2007) *Design, evaluation, and analysis of questionnaires for survey research*. Hoboken, NJ: John Wiley & Sons.

Sax, L.J. (2004) Citizenship development and the American college student. *New Directions for Institutional Research*. **2004**(122),pp.65–80.

Schaad, N.W., Shaw, J.J., Vidaver, A. and Leach, J. (1999) Crop Biosecurity. *APSnet Feature Articles*. [Accessed 12 August 2016]. Available from: http://www.apsnet.org/publications/apsnetfeatures/Pages/CropBiosecurity.aspx.

Schiffrin, D. (2001) Discourse Markers: Language, Meaning, and Context *In*: D. Schiffrin, D. Tannen and H. E. Hamilton, eds. *The Handbook of Discourse Analysis*. Malden and Oxford: Blackwell, pp. 54–75.

Schmidt, R.A. and Bjork, R.A. (1992) New conceptualizations of practice: Common principles in three paradigms suggest new concepts for training. *Psychological science*. **3**(4),pp.207–217.

Schouteten, A. (2013) Chemistry and Ethics in Secondary Education: 25 years of experience with classroom teaching on chemical weapons. *OPCW Today*. **2**(5),pp.30–32.

SCImago (2016) About Us. [Accessed 26 July 2016]. Available from: http://www.scimagojr.com/aboutus.php.

Seo, H. and Thorson, S.J. 2013. From Adversaries to Partners: Academic Science Engagement with North Korea. *Global Asia*. **8**(2),pp.43–47.

SERCEB 2010. The Dual Use Dilemma in Biological Research. *Southeast Regional Center of Excellence for Emerging Infections and Biodefense*. [Accessed 18 August 2016]. Available from: http://www.serceb.org/dualuse.htm.

Sheperd, L.J. (2013) Introduction: critical approaches to security in contemporary global politics *In*: L. J. Sheperd, ed. *Critical Approaches to Security*. London and New York: Routledge, pp. 1–8.

Shinomiya, N. (2009) *Statement by Professor Nariyoshi Shinomiya on behalf of the National Defense Medical College and University of Bradford to the Meeting of States Parties in December 2009 of the States Parties to the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction. 7 December 2009.* Geneva: Biological and Toxin Weapons Convention.

Shinwari, Z.K. (2011) International Consultative Workshop. *Quaid-i-Azam University Department of Biotechnology*. [Accessed 7 August 2015]. Available from: http://www.molecular-systematics.org/index.php?option=com_content&view=article&id=30:international-consultative-workshop&catid=4:events&Itemid=25.

Shinwari, Z.K., Mancini, G.M. and Pinard, W.J. (2011) *An Introduction to Biorisk Management and Dual Use in Life Sciences*. Islamabad, Como and Albuquerque: Quaid-i-Azam University, Landau Network Centro Volta and Sandia National Laboratories.

Silverman, D. (2005) *Doing qualitative research: a practical handbook* 2nd ed. Thousands Oaks, London and New Delhi: SAGE Publications.

Simonite, T. (2005) Bacterial films turn to photography. *news@nature*. [Accessed 8 August 2016]. Available from: http://www.nature.com/doifinder/10.1038/news051121-8.

Sims, N.A. (2006) Legal Constraints on Biological Weapons *In*: M. Wheelis, L. Rózsa and M. R. Dando, eds. *Deadly cultures: biological weapons since 1945*. Cambridge and London: Harvard Univ. Press, pp. 329–354.

Sims, N.A. (2001) *The Evolution of Biological Disarmament*. Oxford and New York: Oxford University Press.

Slovic, P. (1987) Perception of Risk. *Science*. **236**(4799),pp.280–285.

Slovic, P. (1986) Informing and educating the public about risk. *Risk analysis*. **6**(4),pp.403–415.

Slovic, P. and Peters, E. (2006) Risk Perceptions and Affect. *Current Directions in Psychological Science*. **15**(6),pp.322–325.

Smallwood, K. (2009) Biosecurity, Biosafety and Dual Use Risks: Trends, Challenges, and Innovative Solutions. Report. *In*: *Biosecurity, Biosafety and Dual Use Risks: Trends, Challenges, and Innovative Solutions. 13 & 14 November 2009, Villa del Grumello, Como, Italy*. Como: Landau Network - Centro Volta.

Smith, S. (2005) The Contested Concept of Security *In*: *Critical Security Studies and World Politics*. London: Lynne Rienner, pp. 27–62.

Smithson, A. (2011) *Germ Gambits*. Stanford: Stanford University Press.

Snow, C.P. (2012) *The Two Cultures*. Cambridge: Cambridge Univ. Press.

Sokovic, M., Pavletic, D. and Pipan, K.K. (2010) Quality improvement methodologies–PDCA cycle, RADAR matrix, DMAIC and DFSS. *Journal of Achievements in Materials and Manufacturing Engineering*. **43**(1),pp.476–483.

Somerville, M.A. and Atlas, R.M. (2005) Ethics: A Weapon to Counter Bioterrorism. *Science*. **307**,pp.1881–1882.

Starr, C. (1969) Social benefit versus technological risk. *Science*. **165**(3899),pp.1232–1238.

Steensma, H. and Groeneveld, K. (2010) Evaluating a training using the 'four levels model'. *Journal of Workplace Learning*. **22**(5),pp.319–331.

Stern, P.C., Fineberg, H.V. and others 1996. *Understanding risk: Informing decisions in a democratic society*. National Academies Press.

Stirling, A. (2008) Science, Precaution, and the Politics of Technological Risk. *Annals of the New York Academy of Sciences*. **1128**(1),pp.95–110.

Stirling, A. (2007) Risk, precaution and science: towards a more constructive policy debate. *EMBO reports*. **8**(4),pp.309–315.

Stirling, A. (2006) Analysis, participation and power: justification and closure in participatory multi-criteria analysis. *Land Use Policy*. **23**(1),pp.95–107.

Stirling, A. (2003) Risk, uncertainty and precaution: some instrumental implications from the social sciences *In*: *Negotiating Environmental Change*. Edward Elgar Publishing.

Stirling, A. (1999) *On science and precaution in the management of technological risk. Volume I. Synthesis report of case studies*. Sevilla: European Commission Joint Research Centre Institute for Perspective Technological Studies.

Stirling, A. and Mayer, S. (2000) Precautionary Approaches to the Appraisal of Risk: A Case Study of a Genetically Modified Crop. *International Journal of Occupational and Environmental Health*. **6**(4),pp.296–311.

Stone, E.R., Yates, F. and Parker, A.M. (1994) Risk Communication: Absolute versus Relative Expressions of Low-Probability Risks. *Organizational Behavior and Human Decision Processes*. **60**,pp.387–408.

Sture, J.F. and Minehata, M. (2011) Op-Ed - More BTWC Education Needed for Scientists. *Virtual Biosecurity Center*. Available from: www.virtualbiosecuritycenter.org/blog/op-ed-more-btwc-education-needed-for-life-scientists.

Sture, J.F. and Minehata, M. (2010) Seminar Report. Dual use Education for Life Scientists: Mapping the Current Global Landscape and Developments, 15-16 July 2010 *In*: *Dual use Education for Life Scientists: Mapping the Current Global Landscape and Developments*. JSPS and ESRC Seminar Series. Bradford: University of Bradford.

Sweden (on behalf of the European Union) (2009) *EU Cooperative Initiatives and Activities to improve bio.safety and bio-security. Working Paper. BWC/MSP/2009/MX/WP.18*. Geneva: Biological and Toxin Weapons Convention.

Switzerland (2013) *Déclaration liminaire. Intervention prononcée par S.E. M. Urs Schmid, Représentant permanent de la Suisse auprès de la Conférence du désarmement. Genève, 12 aout 2013*. Geneva: Biological and Toxin Weapons Convention.

Tanner, K. and Allen, D. (2004) Approaches to biology teaching and learning: learning styles and the problem of instructional selection—engaging all students in science courses. *Cell biology education*. **3**(4),pp.197–201.

Tanveer, F. & Shinwari, Z.K. (2015a) Interactive Workshops as Tools of Raising Awareness about Dual-Use Issues. In: Zabta Khan Shinwari (ed.). *Dual-Use Education Concerns in Biotechnology. Pakistani Perspective*. Islamabad, Quaid-i-Azam University, IAP the global network of science academies and the Pakistan Academy of Sciences. pp. 50–63.

Tanveer, F. and Shinwari, Z.K. (2015b) Survey on General Awareness about Bio-Security and Dual-Use related Concepts among Educators of Graduate Life Sciences in Pakistan *In*: Z. K. Shinwari, ed. *Dual-Use Education Concerns in Biotechnology. Pakistani Perspective.* Islamabad: Quaid-i-Azam University, IAP the global network of science academies and the Pakistan Academy of Sciences, pp. 38–49.

Tennison, M.N. and Moreno, J.D. (2012) Neuroscience, Ethics, and National Security: The State of the Art. *PLoS Biology*. **10**(3),p.e1001289.

THE (2016) Times Higher Education World University Rankings. *Times Higher Education*. [Accessed 8 August 2016]. Available from: https://www.timeshighereducation.com/world-university-rankings.

Thorndike, E. (1932) *The Fundamentals of Learning*. New York: Teachers College Press.

Tucker, J.B. (2012) Introduction *In*: *Innovation, Dual Use, and Security*. Cambridge, MA: MIT Press, pp. 1–16.

Tucker, J.B. and Sands, A. (1999) An Unlikely Threat. *Bulletin of the Atomic Scientist*. **55**,pp.46–52.

Tumpey, T.M., Basler, C.F., Aguilar, P.V. and Zeng, H. (2005) Characterization of the reconstructed 1918 Spanish influenza pandemic virus. *Science*. **310**,pp.77–80.

Tversky, A. and Kahneman, D. (1975) Judgment under uncertainty: Heuristics and biases *In*: *Utility, probability, and human decision making*. Springer, pp. 141–162.

UK (2013) *We need to talk about compliance: A response to BWC/MSP/2012/WP.11. Working Paper. BWC/MSP/2013/MX/WP.1.* Geneva: Biological and Toxin Weapons Convention.

UK (2008) *Oversight of Emerging Technologies: Examples of UK Approaches to Responsible Development of Science. Working Paper. BWC/MSP/2008/MX/WP.11*. Geneva: Biological and Toxin Weapons Convention.

UK (2005) *The Promulgation and Adoption of Codes of Conduct. Working Paper. BWC/MSP/2005/MX/WP.9*. Geneva: Biological and Toxin Weapons Convention.

Ukraine (2008) *Statement by H.E. Mr. Serhiy Komisarenko, Head of the Delegation of Ukraine, Biological Weapons Convention, 2008 Meeting of Experts. Geneva, August 19, 2008.* Geneva: Biological and Toxin Weapons Convention.

Ullman, R.H. (1983) Redefining Security. *International Security*. **8**(1),pp.129–153.

UNCED (1992) United Nations Conference on Environment and Development Rio Declaration on Environment and Development. Adopted at Rio de Janeiro, June 14, 1992. UN Doc A/Conf.151/5/Rev.1. *International Legal Materials*. **31**(4),pp.874–880.

United Nations (2004) *The Secretary-General's High-level Panel Report on Threats, Challenges and Change, A more secure world: our shared responsibility*. New York: United Nations. Available from: http://www.unrol.org/files/gaA.59.565_En.pdf.

United Nations (2002) *Annex Report of the Policy Working Group on the UN and Terrorism. A/57/273-S/2002/875*. New York: United Nations.

Universidad de Granada (2016) V International Seminar On Biosecurity & Bioterrorism. *Canal UGR. Recursos de Comunicaciòn e informaciòn*. [Accessed 19 August 2016]. Available from: http://canalugr.es/index.php/todas-las-convocatorias/icalrepeat.detail/2016/03/14/18062/-/NmJiYWIwNWQ4YzcwYTdkMjFmZWM3YjE5ZTQ1YjNmMzc.

UNMOVIC (2003) *Unresolved Disarmament Issues. Iraq's Procribed Weapons Programmes*. United Nations Monitoring, Verification and Inspection Commission. Available from: http://www.un.org/Depts/unmovic/documents/UNMOVIC%20UDI%20Working%20Document%206%20March%2003.pdf.

Verband Biologies, Biowissenschaften und Biomedizin (2010) Erklärung zur Biologischen Sicherheit. [Accessed 18 August 2016]. Available from: https://www.vbio.de/vbio/content/e26/e29/e23978/e29133/filetitle/110205_ErklrungKBFundVBIOzurBiologischeSicherheit_ger.pdf.

Vieira, M.A. (2007) The Securization of the HIV/AIDS Epidemic as a Norm: A Contribution to Construtivist Scholarship on the Emergence and Diffusion of International Norms. *Brazilian Political Science Review*. **1**(2),pp.137–181.

Volkwein, J.F., Lattuca, L.R., Harper, B.J. and Domingo, R.J. (2006) Measuring the Impact of Professional Accreditation on Student Experiences and Learning Outcomes. *Research in Higher Education*. **48**(2),pp.251–282.

Vrjling, J.K., van Hengel, W. and Houben, R.J. (1995) A framework for risk evaluation. *Journal of Hazardous Materials*. **43**(3),pp.245–261.

Waever, O. (1995) Securitization and Desecuritization *In*: R. D. Lippschutz, ed. *On Security*. New York: Columbia University Press, pp. 46–86.

Wahlberg, M., Leitenberg, M., Lei and Zanders, J.P. (2000) The Future of Chemical and Biological Weapons Disarmament in Iraq: From UNSCOM to UNMOVIC *In*: *SIPRI Yearbook 2000. Armaments, Disarmament and International Security*. Oxford and New York: Oxford University Press.

Wall, K.D. (2011) The Kaplan and Garrick definition of risk and its application to managerial decision problems. *DRMI Naval Postgraduate School Working Papers*.

Wampler, R.A. and Blanton, T.S. (2001) *The September 11th Sourcebooks Volume V: Anthrax at Sverdlovsk, 1979. U.S. Intelligence on the Deadliest Modern Outbreak*. Washington, DC: George Washington University.

Weimer, M. (2002) *Learner-centered teaching: five key changes to practice*. San Francisco, CA: Jossey-Brass.

Weiss, R.S. (1995) *Learning From Strangers: The Art and Method of Qualitative Interview Studies*. Free Press.

Wellcome Trust (2003) *Position Statement on Bioterrorism and Biomedical Research*. Wellcome Trust. Available from:

https://wellcome.ac.uk/funding/managing-grant/managing-risks-research-misuse.

Wheelis, M. (1999a) Biological Sabotage in World War I *In*: E. Geissler and J. E. von Courtland Moon, eds. *Biological and Toxin Weapons: Research, Development and Use from the Middle Ages to 1945*. SIPRI Chemical & Biological Warfare Studies. Oxford and New York: Oxford University Press, pp. 35–62.

Wheelis, M. (1999b) Biological Warfare before 1914 *In*: E. Geissler and J. E. von Courtland Moon, eds. *Biological and Toxin Weapons: Research, Development and Use from the Middle Ages to 1945*. SIPRI Chemical & Biological Warfare Studies. Oxford and New York: Oxford University Press, pp. 8–34.

Wheelis, M. and Sugishima, M. (2006) Terrorist Use of Biological Weapons *In*: M. Wheelis, L. Rózsa and M. R. Dando, eds. *Deadly cultures: biological weapons since 1945*. Cambridge and London: Harvard Univ. Press, pp. 284–303.

Whitby, S. and Dando, M.R. (2010a) Biosecurity Awareness-raising and Education for Life Scientists: What Should be Done Now? *In*: *Education and Ethics in the Life Sciences*. Canberra: ANU E Press.

Whitby, S. and Dando, M.R. (2010b) *Effective Implementation of the BTWC: The Key Role of Awareness Raising and Education*. Department of Peace Studies, University of Bradford.

Whitby, S., Novossiolova, T., Walther, G. and Dando, M.R. (eds.). (2015) *Preventing Biological Threats: What You Can Do*. Bradford: University of Bradford.

White House (2002) *The National Security Strategy of the United States of America*. [Accessed 8 August 2016]. Available from: http://www.state.gov/documents/organization/63562.pdf.

WHO (2012) WHO Preliminary Consultation on H5N1 Research Issues. *World Health Organisation*. Available from: http://www.who.int/mediacentre/events/meetings/2012/h5n1_research_issues/en/index.html.

WHO (2010) *Responsible Life Sciences Research for Global Health Security*. Geneva: World Health Organization. Available from: http://www.who.int/csr/resources/publications/HSE_GAR_BDP_2010_2/en/index.html.

WHO (2006) *Biorisk Management: Laboratory Biosecurity Guidance*. Geneva: World Health Organization.

WHO (2005) *International Health Regulations*. Geneva: World Health Organization.

WHO (2004) *Laboratory biosafety manual* 3rd ed. Geneva: World Health Organization.

Willis, H.H., Morral, A.R., Kelly, T.K. and Medby, J.J. (2006) *Estimating terrorism risk*. Rand Corporation.

World Economic Forum (2013) *Global Risks 2013*. Geneva: World Economic Forum. [Accessed 8 August 2016]. Available from: http://www3.weforum.org/docs/WEF_GlobalRisks_Report_2013.pdf.

World Medical Association (2002) *Declaration of Washington on Biological Weapons* [Online]. Washington, DC: World Medical Association. [Accessed 8 August 2016]. Available from: http://www.wma.net/en/30publications/10policies/b1/.

Wynne, B. (1983) Redefining the issues of risk and public acceptance: the social viability of technology. *Futures*. **15**(1),pp.13–32.

Young, S., Willis, H.H., Moore, M., Engstrom, J.G., National Defense Research Institute, Acquisition and Technology Policy Center and Cooperative Threat Reduction Program of the U.S. Department of Defense (2014) *Measuring Cooperative Biological Engagement Program (CBEP) performance: capacities, capabilities, and sustainability enablers for biorisk management and biosurveillance*. Washington, DC: National Academies Press.

Zhang, Y., Zhang, Q., Kong, H., Jiang, Y., Gao, Y., Deng, G., Shi, J., Tian, G., Liu, L., Liu, J., Guan, Y., Bu, Z. and Chen, H. (2013) H5N1 Hybrid Viruses Bearing 2009/H1N1 Virus Genes Transmit in Guinea Pigs by Respiratory Droplet. *Science*. **340**(6139),pp.1459–1463.

Zilinskas, R.A. (2000) Possible Terrorist Use of Modern Biotechnology Techniques *In*: *Proceedings of the Conference Biosecurity and Bioterrorism, Rome, September 2000*. Como: Landau Network Centro Volta, pp. 43–56.

Appendices

Online investigation on content data tabulation model

Survey of HEIs on existing biosafety, biosecurity, biorisk management, laboratory management and bioethics contents and contact persons

N	Country	Name of HEI	Type of HEI	Affiliation, Dept., Institute, School or Campus	Activity or Degree Type or Level	Activity or Degree Title or Name	Link	Comments and Notes	Y/N/?	Biorisk Management/Safety/Security/Laboratory Management Content	Y/N/?	Ethics/Bioethics/Responsible Conduct of Research Content	Contact Person(s)
1													
2													
3													

Sample of questionnaire survey model on professors

Name (optional):

Country (optional):

Institution (optional):

Function/Role/Job Title/Position (optional):

Email address (optional, if applicable):

Area of your Institute/Department/Faculty of affiliation (optional):

☐ Biology

☐ Biomedicine

☐ Biotechnology

☐ Engineering

☐ Environmental Sciences

☐ Humanities

☐ Medicine

☐ Natural Sciences

☐ Pharmacy

☐ Other

Discipline(s) taught: ________________________________

Level/Degree of intervention:

☐ Bachelor
☐ Master
☐ Doctorate

Approximate number of students taught per year: _________

Does your university currently include considerations/Do students currently receive education on biosafety (as defined below) in the education of students?

> *Biosafety: the containment principles, technologies and practices that are implemented to prevent unintentional exposure to biological agents and toxins or their accidental release (WHO Laboratory Biosafety Manual, 2004)*

☐ Yes, in courses I teach

☐ Yes, in other courses

☐ No

☐ I do not have such information

If yes, could you provide more information on the extent, nature and context of such considerations/education?

Description	Included	Referen	Modes of	Hou	Notes

	in the course…	ces	teaching	rs/c redi ts	

Does your university currently include considerations/Do students currently receive education on biosecurity (as defined below) in the education of students?

> *Biosecurity: Protection, control and accountability measures implemented to prevent the loss, theft, misuse, diversion, or intentional release of biological agents and toxins and related resources, as well as unauthorized access to, retention, or transfer of such material (WHO Laboratory Biosecurity Guidance, 2006); not limited to biosecurity within the laboratory.*

☐ Yes, in courses I teach

☐ Yes, in other courses

☐ No

☐ I do not have such information

If yes, could you provide more information on the extent, nature and context of such considerations/education?

Description	Included in the course…	Referen ces	Modes of teaching	Hou rs/c redi ts	Notes

In the taught modules, do you make any reference to the following topics:

Biosecurity

☐ Yes (course: ___________)

☐ No

Biosafety

☐ Yes (course: ___________)

☐ No

Bioethics

☐ Yes (course: ___________)

☐ No

Biological weapons/ the Biological and Toxin Weapons Convention

☐ Yes (course: ___________)

☐ No

"Dual-Use"/misuse

☐ Yes (course: ___________)

☐ No

"Codes of Conduct”

☐ Yes (course: ___________)

☐ No

Laws prohibiting Biological Weapons

☐ Yes (course: ___________)

☐ No

Are alternative concepts of biosafety/biosecurity to the above ones also used?

☐No, they are used in the same context: prevention of harm from pathogens and toxins

☐Yes, they are used in the context of control of agricultural contamination

☐Yes, they are used in the context of protection of biodiversity

☐Yes, they are used in the context of GMOs regulation

If biosafety and/or biosecurity are not taught, what is the reason in your opinion?

☐These subjects are currently not a high priority, compared to other subjects/we don't think these topics are relevant to our syllabi

☐Lack of subject matter knowledge, teaching capacity, resources or expertise

☐Lack of teaching time in courses/curricula

☐Other (please describe): ________________________________

Have you ever attended any training, workshop or seminars on biosafety, biosecurity, biorisk management, and/or potential misuse/dual-use issues?

☐Yes (please provide detail ______________________)

☐No

If yes, could you incorporate what you learned into your teaching?

☐Yes

☐No

☐Not Applicable (I do not have teaching responsibilities)

Do you have any plans to change your course or module to accommodate such topics?

☐Yes

☐No

☐Not Applicable (I do not have teaching responsibilities

Are you aware of any national or international law, regulation or oversight body governing life science research and/or the publication of research/prohibiting the non-peaceful use of life science research?

☐Yes (please provide detail ______________________)

☐No

Do existing training programs include courses on bioethics, medical ethics or research ethics?

☐Yes, in the courses____

☐No, they are not included

☐I don't know

If yes, do they include considerations on dual-use issues, potential misuse and/or bioterrorism threats, relevant for biosecurity?

☐Yes, ethics considerations relevant for biosecurity are included

☐No, ethics considerations relevant for biosecurity are not included

☐I don't know

Please identify the three learning objectives that you believe are most important for your students related to biosafety and biosecurity.

a. ____
b. ____
c. ____

How would you define the priority of incorporating new education on biosafety and biosecurity (biorisk management) in the academic programs of your institution/do you think that awareness on these topics should be raised among current and perspective life scientists in your country?

☐Currently there is no need for new education on biosafety and biosecurity/Not important/No

☐High priority: more urgent than other new topics that could be incorporated/Very important/Yes

☐Average priority: they should be incorporated together with other new topics/Important

☐Low priority: there are other, more urgent, new topics to be incorporated/Less important/Neutral

If new biosafety and biosecurity (biorisk management) education were to be integrated in the programs, what would be your opinion of the following possible strategies?

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
New content on biorisk management should and can be integrated into existing courses/modules, expanding their hours/credits					
New content on biorisk management should be inserted in extra-curricular activities, as expanding hours or credits for existing courses is very difficult					
Biorisk management should be the topic of elective activities or courses					
Biorisk management should be developed as a specific course with dedicated credits, that will be added to curricula in the next available review					
Current trainers at the institute/faculty at the university have the necessary background and training skills to deliver biorisk management content					

Which of the following best describes the process of introducing new course(s) with dedicated credits into the academic program of your institution (check all that apply)?

☐The process to approve new courses is internal to the institution and decisions on changing programs can be taken and implemented directly

☐The process of approving new courses is internal to the institution, but it does require multiple formal review and approval by various management levels

☐The process of approving new courses proposed by the institution depends on the review and approval of organizations external to the institutions, which should authorize and provide resources (such as the Ministry, or the University Senate)

☐ New courses are designed via coordination mechanisms self-managed at the professional or academic level (such as professional associations/orders; association of deans; associations of course coordinators, etc)

☐The introduction of new courses is derived from external national standards, like training programs or curricula decided at the level of competent Ministry (Higher Education, Public Health, or Animal Resources)

☐None of the above (please explain):_____________________________

Are you interested in being involved in activities aimed at raising awareness on these topics and/or discussing at a national or international conference, workshop or training event?

☐Yes

☐No

Please use the space below to include any further comments, thoughts, remarks or ideas you would like to share.

Sample of questionnaire survey model on students

Name (optional):

Age (optional):

Sex (optional):

Degree studied:

Discipline/subject studied:

University/Institution:

Country/Province/District:

Email address (optional):

Have you ever heard about the following?

Bioethics

☐ Yes

☐ No

Biosafety

☐ Yes

☐ No

Biosecurity

☐ Yes

☐ No

Biological weapons/bioweapons

☐ Yes

☐ No

Bioterrorism

☐ Yes

☐ No

Dual use research/ “dual-use”

☐ Yes

☐ No

Biological and Toxin Weapons Convention

☐ Yes

☐ No

Codes of Conduct

☐ Yes

☐ No

What do you understand of the following terms (“one line definitions”)?

Bioethics:

Biosafety:

Biosecurity:

Bioweapons:

Bioterrorism:

Dual-use research/dual-use:

Have you ever studied anything related to the above-mentioned concepts in your educational career?

☐Yes (please specify what and where? ________________)

☐No

Which source of information you consider more useful in developing concepts and learning?

□ Lectures

□ Reading

□ Visual Animations

□ Video Films

□ Workshops

□ Others (specify) __________

Are you involved in any kind of life science or biological-related research?
☐Yes

☐No

Do you think that your field of study involves techniques that have the potential to be misused?
☐Yes

☐No

Do you know any local or international organization/ Research group working on dual-use research regulation?
☐Yes (please specify ________________)

☐No

Do you know any national or international legislation or regulation prohibiting the non-peaceful use of life sciences research?
☐Yes (please specify ________________)

☐No

Do you know any examples of “codes” of responsible conduct which apply to life scientists, biotechnologists and related professionals?
☐Yes (please specify ________________)

☐No

Have any of your teachers delivered a lecture dealing with topics such as dual use research, biosecurity, bioterrorism etc.?
☐Yes

☐No

Is your University/College offering a separate course covering topics like bioethics, biosafety, biosecurity and dual use research?
☐Yes

☐No

If YES, can you briefly describe the contents of the course(s)
Have you ever attended any conference or seminar on topics like bioethics, biosecurity, biosafety and responsible conduct of science?

☐Yes

☐No

Have you ever heard about the concept of “Responsible Conduct of Science”?
☐Yes

☐No

Please indicate your opinion on the following items:

	Strongly disagree/No	Disagree	Neutral	Agree	Strongly Agree/ Yes
Laboratory setups at educational and research institutes can be misused or exploited for preparation of materials for hostile purposes/Do you think that laboratory set-ups can be used for preparation of material for terrorist activities?					
Undesired elements can gain access to scientific techniques for hostile activities/Do you think that terrorists can access the scientific techniques?					
Educational and research institutions should include study material on dual use, biosafety and biosecurity in your course work./Do you think that your institution should include study material about dual-use, biosafety and biosecurity in your course work?					
National policy related to dual use research and biosecurity should be developed in your country/Do you support the national policy development about dual-use and biosecurity in your country?					
Scientific journals should have policies regulating the publication of dual use research/Should scientific journals have policies regarding publication of dual-use research?					
The misuse of biological knowledge and techniques is potentially destructive.					

Any Comments/Remarks you would like to share:

Samples of post-instruction questionnaire survey models
Sample 1

Pre-seminar questions (if applicable)

What is currently meant with "dual use" in the life sciences?

- ☐ The uncertainty on results characterizing new technologies
- ☐ The potential of obtaining positive results beyond expectations
- ☐ The possibility that they are applied both for peaceful and hostile purposes
- ☐ The ambiguity of life science and technology

Laboratory biosafety refers to:

- ☐ Measures and policies for preventing the deliberate misuse of pathogens
- ☐ Measures for preventing theft and loss of pathogens
- ☐ Measures for preventing the unauthorized access to pathogens and toxins
- ☐ Measures for preventing the unintentional exposure to biological agents and toxins, or their accidental release

Which statement about laboratory biosecurity is NOT true?

- ☐ It comprises policies and practices that require life scientists to consider the ethical, social and legal implications of their work
- ☐ It comprises measures and policies against the theft and loss of pathogens
- ☐ It comprises measures and policies against the unauthorized access to pathogens and toxins
- ☐ It comprises measures and policies that seek to prevent the intentional release of pathogens and toxins

Which was the first International treaty to prohibit the use of toxic and biological weapons?

- ☐ The Hague Declaration, 1907
- ☐ Geneva Protocol, 1925
- ☐ Biological and Toxin Weapons Convention, 1972
- ☐ Chemical Weapons Convention, 1993

What do you hope to gain from today's session

- ☐ To learn about dual use/misuse/security issues
- ☐ To learn about the broader context of life science (e.g. social, ethical, legal aspects, etc)
- ☐ To have contacts with diverse opinions and experiences
- ☐ To interact with fellow colleagues
- ☐ To acquire new skills and experience
- ☐ Other____

Post-Seminar questions

Are the topics of the seminar interesting?

- ☐ Very interesting
- ☐ Quite interesting
- ☐ Not so much
- ☐ Not at all

Was your previous knowledge sufficient to follow the seminar?

☐ Yes
☐ Yes, even if having further information would have been helpful
☐ No, but I could follow the seminar easily anyway
☐ No, and this proved difficult

Were the topics addressed discussed in other courses?

☐ No
☐ Yes, but useful to deepen understanding
☐ Yes, a few
☐ Yes and too many

Did the seminar touch upon contemporary themes related to research?

☐ Yes and I found it interesting
☐ No, but this is due to the type of the seminar
☐ Yes, but too much
☐ No, this is an important aspect not addressed in the seminar

Had you any prior knowledge about the potential "hostile use" of life sciences?

☐ Yes
☐ No

Do you think that your knowledge and understanding of the following specific aspects have been developed after this seminar?

- History of Biological Weapons
  - ☐ Yes, very much
  - ☐ Yes
  - ☐ Not very much
  - ☐ Not at all
- The Biological and Toxin Weapons Convention
  - ☐ Yes, very much
  - ☐ Yes
  - ☐ Not very much
  - ☐ Not at all
- The problem and the risks of "dual-use"
  - ☐ Yes, very much
  - ☐ Yes
  - ☐ Not very much
  - ☐ Not at all
- Tools and policies of "biosecurity"
  - ☐ Yes, very much
  - ☐ Yes
  - ☐ Not very much
  - ☐ Not at all

What are the important things to remember about dual-use/misuse?

☐ Life scientists should be aware of the social, ethic and legal implications of their work
☐ Life scientists should be aware both of the national and international regulations relevant to their work
☐ Cost-benefit analysis is an essential element in mitigating the risks associated with life science research of concern
☐ There are potential risks and impacts on society to consider
☐ It is important to balance freedom of research and regulation of science

☐ Other ____

Laboratory biosafety refers to:

☐ Measures and policies for preventing the deliberate misuse of pathogens
☐ Measures for preventing theft and loss of pathogens
☐ Measures for preventing the unauthorized access to pathogens and toxins
☐ Measures for preventing the unintentional exposure to biological agents and toxins, or their accidental release

Which statement about laboratory biosecurity is NOT true?

☐ It comprises policies and practices that require life scientists to consider the ethical, social and legal implications of their work
☐ It comprises measures and policies against the theft and loss of pathogens
☐ It comprises measures and policies against the unauthorized access to pathogens and toxins
☐ It comprises measures and policies that seek to prevent the intentional release of pathogens and toxins

What is currently meant with "dual-use" in the life sciences?

☐ The uncertainty on results characterizing new technologies
☐ The potential of obtaining positive results beyond expectations
☐ The possibility that they are applied both for peaceful and hostile purposes
☐ The ambiguity of life science and technology

Which was the first International treaty to prohibit the use of toxic and biological weapons?

☐ The Hague Declaration, 1907
☐ Geneva Protocol, 1925
☐ Biological and Toxin Weapons Convention, 1972
☐ Chemical Weapons Convention, 1993

Do you think that some aspects of research that you study could present a "dual-use" issue?

☐ Yes
☐ No
▪ If yes, please explain what you think could be done to prevent the potential hostile applications of this research and minimize concerns over the possibility of dual use

____

What you would suggest to improve this seminar? Can you identify any other relevant topics which should be incorporated into our future seminars?

____

Would you recommend seminars like today's to other students?

☐ Yes
☐ No

Are you enrolled in a course?

☐ Yes
☐ No

What is the level of your current degree course/research?

- ☐ Undergraduate
- ☐ Graduate (Master)
- ☐ PhD
- ☐ Post-Doctoral

What is your field of study/research?

- ☐ Biology
- ☐ Biotechnology
- ☐ Microbiology
- ☐ Medicine
- ☐ Chemistry
- ☐ Toxicology
- ☐ Non-Life Science (please indicate): ________________
- ☐ Social Science (please indicate):___________________
- ☐ Other (please indicate): __________________________

Sample 2

Title of the event/seminar/workshop/course:______________

I am satisfied with the event/seminar/workshop/course

- ☐ Strongly agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly disagree
- ☐ Strongly disagree

I was informed of the objectives of the event/seminar/workshop/course

- ☐ Strongly agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly disagree
- ☐ Strongly disagree

The quality and content of the event/seminar/workshop/course and training materials met my expectations / The overall quality of the event/seminar/workshop/course was high

- ☐ Strongly agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly disagree
- ☐ Strongly disagree

The event/seminar/workshop/course lived up to my expectations / This event/seminar/workshop/course met my prior objectives and expectations

- ☐ Strongly agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly disagree
- ☐ Strongly disagree

The event/seminar/workshop/course presented information clearly / The ability, clarity and completeness of the trainer were adequate when responding to trainee questions / Are contents of the seminar articulated in a coherent framework?

- ☐ Strongly agree / Yes
- ☐ Agree / Contents are not very connected with each other
- ☐ Neutral / No, teachers can't show clearly the connections
- ☐ Disagree
- ☐ Strongly disagree
- ☐ Strongly disagree

The event included relevant group participation, discussions and interaction

- ☐ Strongly agree
- ☐ Agree
- ☐ Neutral

- ☐ Disagree
- ☐ Strongly disagree
- ☐ Strongly disagree

The information I learned within the event/seminar/workshop/course was important and relevant to my current position/job / The event/seminar/workshop/course is relevant to my job

- ☐ Strongly agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly disagree
- ☐ Strongly disagree

What improvements would you suggest for the event/seminar/workshop/course?

Sample 3

Title of the event/seminar/workshop/course:

After this event/seminar/workshop/course, I…

Know [learning objective]

- ☐ Strongly agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly disagree
- ☐ Strongly disagree

Feel [learning objective]

- ☐ Strongly agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly disagree
- ☐ Strongly disagree

Am able to [learning objective]

- ☐ Strongly agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly disagree
- ☐ Strongly disagree

Semi-structured interview information and content sheet

Information and Consent Sheet

Please read this page, it describes the purpose of the research, your involvement, what information will be collected and how it will be used and stored.

Researcher: Giulio Mancini, g.m.mancini@student.bradford.ac.uk

Research Supervisor: Dr. Simon Whitby

Thank you for considering participating to this research. The purpose of this study is to investigate the role of education of students of life and health sciences and technology about security issues, in particular but not limited to the risk of deliberately caused disease. We hope to understand if and how educational programmes can raise the awareness of young scientists on a highly debated topic in policy circles, so that scientists can contribute to, on the one hand, risk mitigation and, on the other hand, formulation of risk assessment and governance that does not unduly burden scientific practice and research.

The research uses, among other quantitative and qualitative data collection methods, interviews to learn about status and opinion of educators and course coordinators in life science faculties. We would like to interview you as an educator who has been involved in initiatives regarding this topic.

All the information that we collect about you during the interview will be kept confidential and only the research team will have access to it. The information may be used for analysis in the research and in connected academic publications, but you will not be identified in any material. The audio recordings of the interview will be kept secure and accessible only by the research team; they will be transcribed in an anonymous way and they will be destroyed at the completion of the research. Ethics approval has been granted by the Chair of the Humanities, Social and Health Sciences Research Ethics Panel at the University of Bradford on 3rd December 2014.

If you decide to take part, you should sign one copy of this sheet and give it back to the researcher, and retain a second copy. Should you decide to withdraw from the study and/or have your information cancelled, you can request it at any time to the researcher.

Also if you would like to discuss the research further or have any questions please do not hesitate to contact us.

Thank you!

Printed name:_________________________________ Date: __________

Signature____

Semi-structured interview schedule

- Information and consent form; ask permission to record.
- Introduction; explanation of objectives of the study; how the interview will fit in the research; who I am interviewing, how and why are interviewees selected.
- Can you walk me through how did you get involved into education on these subjects? What is your recollection?
- What do you think can be the role of education on these subjects, if any?
- Do you think there has been an evolution or change of the educational offerings since you first started being interested/involved in these topics? If yes, can you elaborate more? What would that change be/has been?
- Explanation of the four-levels models to evaluate impact of training and education.
- Do you think (your) students liked these subjects? If yes, how, how much, and how can you tell? If not, why not?
- Do you think the initiatives to promote education on these subjects developed students' learning (knowledge, skills)? If yes, how, how much, what learning, and how can you tell? Could you tell me why you think that happened? If not, why not?
- Do you think students changed their behaviour as a consequence of these educational initiatives? Or, if observing this change on the same students was not possible, do you have the impression that cohorts of students who took this education have a different behaviour than those who did not? If yes, how could you observe or measure this difference? If not, why did this not happen?
- Did you notice a result at the organizational level that you would link completely or in part to educational initiatives? Did you notice an impact on the level of biosafety or biosecurity risks, but especially the latter and deliberate disease risks? If yes, how could you observe these changes? If not, why not? Could that happen in the future? How could we tell that? Some examples to elicit responses, if necessary, may include: changes in safety or security incidents, new procedures being drafted, increased use of screening processes; reformed oversight systems to include security considerations; other result (risk) indicators.