Design Support for Constructing Pilot Training Programmes

By

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Abstract

Deciding how to construct a training programme or a training exercise, and especially what and how training media and methods should be selected to deliver effective and efficient training is an ongoing endeavour that preoccupies training analysts and designers alike. There are many interactions and dependencies that one has to take into consideration when making decisions, about cost, safety, or interactions between various components of a training system (e.g. between various types of media; between media and methods; between media, methods and trainees) to produce the desired outcome.

The focus of this PhD research is to develop an understanding of the challenges faced by decision-makers within the military fast-jet training domain in constructing the training and, further, to develop solutions that support the decision-making effort.

A significant challenge faced by decision-makers in constructing training programmes, identified through this research, is the ever increasing amount of information that they need to have at their disposal to enable fully informed decision-making and the lack of methods and tools to facilitate the management and analysis of this information. This research specifically investigated the problem of media selection to construct the training and developed a series of concept solutions to support differentiation between training media, assessment of trainees previous experiences, management of TNA outputs, selection of instructional methods and understanding of the cognitive relationship between media, method and trainee.

The thesis firstly introduces the problem to be addressed; the research context and research questions set to be answered. This research, sponsored by Engineering and Physical Science Research Council (EPSERC) and BAE Systems, is preceded by another BAE Systems funded research project (the Training Optimisation Case Study), which provided the background for the work presented in this thesis. Secondly, it reviews the literature relevant to the subject matter to understand the current state of knowledge in the area of: UK RAF training programmes construction and training media selection; assessment of competencies; impact of media and method on learning; development of decision making support systems; and construction and management of knowledge.

The main part of the work presented in this thesis is the development of a series of support solutions to aid the decision-making process of construction of UK fast-jet pilot training. These include: TNA output Analysis (ToA) tool; Trainee Contextual Proficiency Profile (TCPP) tool; Training Media Classification Framework; models that map the cognitive relationship between media, method and trainee, and a unified Framework of Selection of Instructional Process alongside a novel approach towards training media selection.

This research work was initially scoped through an exploratory study (a case study) into the domain area, followed by requirements elicitation. This part of research helped at identifying the issues within the problem area and in defining the research questions. The TCPP and ToA were verified through two case studies and presented alongside the rest of the research to the customer (BAE Systems) that gave positive feedback on the research outcomes.

Acknowledgments

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GLOSSARY

A

ABTC = Air Battle Training Centre
AFT = Advanced Fling Training

B

BFT = Basic Flight Training

C

CATT = Combine Arms Tactical Training
CR = Combat Ready

D

DSAT = Defence Systems Approach to Training
DSS = Decision Support System
DE&S = Defence Equipment and Support
DMSS = Decision Making Support Systems (a concept demonstrator system that presents the TCPP & ToA tools)

E

EFT = Elementary Flight Training
EO = Enabling Objective

F

FL = Front Line

H

HTA = Hierarchical Task Analysis

J

LVC = Live, Virtual, Constructive
JSP = Joint Service Publication

K

KSA = Knowledge, skills and Attitudes

L

LCR = Limited Combat Ready

M

MMST = Method and Media Selection Tool
MEC = Mission Essential Competences
MT = Mission Training
MOD = Ministry of Defence
MIS = Management Information System

N

NAO =National Audit Office

O

OCU = Operational Conversion Unit
OTA = Operational Task Analysis

R

RAF = Royal Air Force

S

SME = Subject Matter Expert
SES = Sequential Exploratory Strategy
SE = Systems Engineering

T

TNA = Training Needs Analysis
TO = Training Objective
TCPP = Trainee Contextual Proficiency Profile
ToA = TNA output Analysis

U

UML = Unified Modelling Language

Chapter 1

INRODUCTION

"We cannot solve a problem from the same level of consciousness that created it. We must learn to see the world anew".

Albert Einstein

This chapter introduces the PhD project and provides the rational for the research direction that was followed. It will start by presenting the stakeholders (funding bodies) requirements and information on a previous investigation into the same problem area as this PhD project addresses (section 1.1 Project background).

The research conducted to identify exact issues to be addressed by this project is presented in section 1.3 Problem space, and the research questions set to be answered, as well as the outputs of research are presented in section 1.4 Research Questions and Outputs. A visual representation of the overall steps taken to complete the project as well as the outcomes from each of the steps is presented in Figure 1.1:

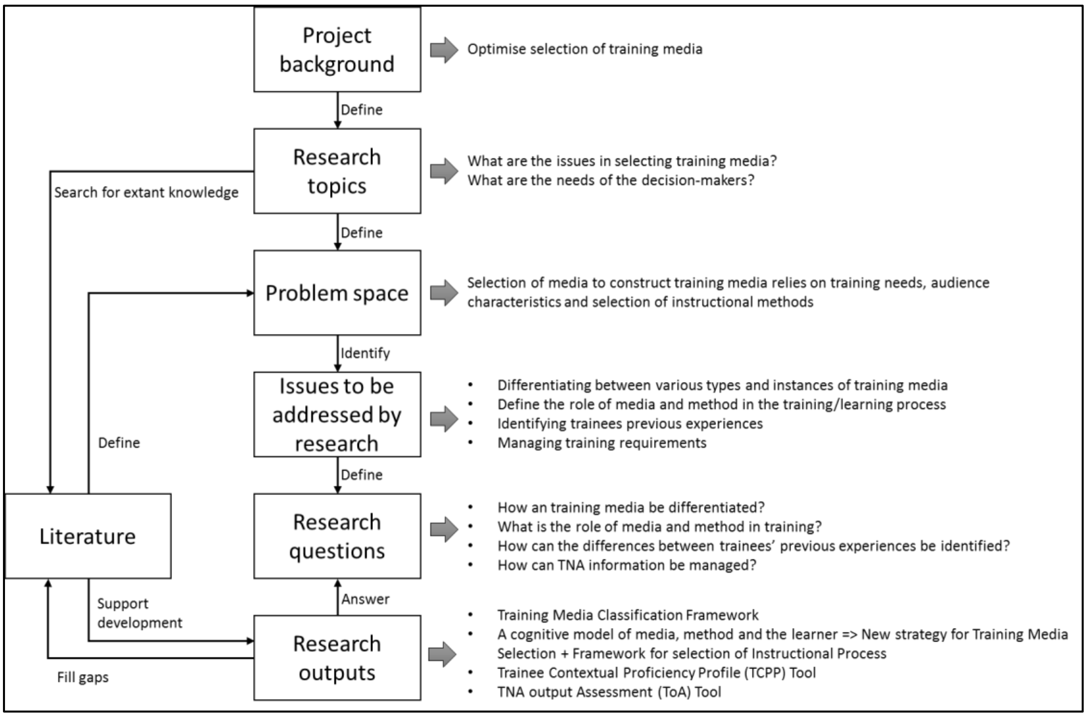

Figure 1.1: PhD Project research steps

1.1 Project background

1.1.1 Project requirements

Initiated by the Engineering and Physical Science Research Council (EPSRC) and BAE Systems, this PhD research project was created with the purpose of providing solutions to support the development of cost-effective fast jet (military) pilot training programmes. Furthermore, it was proposed that the research project should focus on the creation of an approach with a support framework or tool through which the selection of training media could be optimised so as to ensure the complete satisfaction of training objectives using the most appropriate blend of training media. The developed approach had to provide a repeatable and quantifiable solution to support the decisions made by trainers in the construction of training programmes and required the incorporation of qualitative information within a numerical decision support tool in a way that can be rigorously justified.

The categories of training media options to be considered were: Live, Virtual and Constructive (LVC); where Live is understood as being a real-world platform in a real environment operated by a real person, Virtual as a synthetic platform (e.g. simulator) operated by a real person, and Constructive as a computer generated entity controlled by either a virtual entity (e.g. computer programme) or a real person (e.g. role-player).

Over the years, synthetic training solutions such as Virtual and Constructive media have been steadily developed and introduced in pilot training as a practical and safe alternative to live training, to rehearse typical tasks in operational scenarios. As a whole, training must ensure learning, transfer and retention, but this must be achieved through programmes that are flexible, safe and resource-efficient. As such, training programmes are built from a combination of live flying, synthetic environments, mixed live and synthetic, computer and classroom-based activities. The construction of training programmes therefore requires optimisation of the selection of media in a way that is tailored to meet individual and operational needs.

1.1.2 Precursor project

Around the same time as the research project presented in this thesis started, another similar research project conducted by BAE Systems and Loughborough University was ending; *"The Training Optimisation Case Study"* conducted by Whittle and Valiusaityte (2010). The precursor study looked at the potential to develop or select an optimisation technique that would support the selection of an optimal mix of Live, Virtual and Constructive media to construct a training exercise.

In their research, Whittle and Valiusaityte took a mathematically orientated approach to develop a model and formulated the training regime problem as a multi-objective optimisation task. Whittle and Valiusaityte made the assertion that given the trainee skills required to be developed through training, the model would propose an LVC balance that would best satisfy the training requirements with due consideration to cost, safety, efficiency and effectiveness (Whittle and Valiusaityte, 2010).

To develop the model, aircrew training Subject Matter Experts (SMEs) were asked to quantify a variety of variables required by the model. These variables were related to trainee skills improvement (e.g. maintain formation) in terms of the effect that the variable (e.g. trainee role in exercise, wingman) had on the potential to develop the specified skills. During this stage of the study, the researchers discovered that determining the values to be assigned to the various variables is quite challenging, the main reason being that no simple or direct correlation between the specified skills and the linked variables was found.

Whittle and Valiusaityte (2010) study provides valuable insight into the problem area that this thesis addresses. That is, that the decision-making problem for which a support tool is required lacks structure, has a high degree of complexity and there are challenges in identifying and quantifying all the possible variables upon which the decision-making relies. Their findings raised questions regarding the pursuit of optimisation as a means to select the media for training, as it was suggested by the project stakeholders.

1.1.3 Optimisation

Optimisation, in a wider scope, refers to a numerical technique often employed to maximise the benefits of a system, its outputs, or its capabilities, while reducing the inputs or resources, such as time, costs, workload, etc. This however, does imply that the output generated by the non-optimised system is the desired one; i.e. there is the assumption that the method is right for the training required to achieve the desired outcome.

The main purpose of optimisation is to either solve a problem that may arise in a given system (Baldick, 2006; Taha, 2010) or to increase a system efficiency and/or effectiveness (Whittle and Valiusaityte, 2010). In order to apply this approach, certain steps have to be followed and specific conditions have to be met. First, the scope and objectives that one wants to achieve must be clearly defined as well as the boundaries under which the system under consideration operates. Second, a good enough abstract model of the real world system under study must be constructed. These will help further at constructing a mathematical representation of the identified problem. (Taha, 2010)

There are various computational techniques that can be applied to optimise a system, such as optimisation algorithms, heuristic algorithms and interactive methods that can be used on their own or in combination. However, the model of the system (Taha, 2010), the optimisation objective and the set of constrains (Baldick, 2006) will determine what type of technique can then be applied (Taha, 2010) and if the solution will be feasible (Baldick, 2006).

Conclusions

While there is certainly a valid objective to quantify the constituents of a training programme and use this information to determine an optimum set of training media options for the purpose of removing subjectivity and gain a repeatable and quantifiable approach solution, Whittle and Vliusaityte (2010) study shows that there is required an enormous amount of subjectivity to determine and assign the values of the variables in the first place. Therefore, there is a valid concern that the output of any tool built to ‘objectively’ select the media for training might be equally subjective while at the same time it could be lacking the experienced judgement of experts (Whittle and Valiusaityte, 2010).

1.1.4 Project aim

The purpose of this PhD project is to provide solutions to support the selection of media for construction of UK pilot training programmes. As it was suggested (see section 1.1 Project background) by the main project stakeholders (e.g. the customer: BAE Systems), one way of achieving this goal is to quantify the variables based on which the decision of selecting the training media relies on and to apply a suitable optimisation technique to obtain an optimal combination of media. However, Whittle and Valiusaityte (2010) study shows that the realisation of such a model is very unlikely given the current knowledge regarding the impact that certain types of media have on training. Furthermore, the study shows that the variables involved in defining and evaluating the possible effects are greatly context dependent and that there are too many factors that influence the choice of specific values to quantify the impact of factors.

When searching or developing an optimisation type of approach-solution, the quality of the solution will depend on the completeness of the model through which the real world parameters are lumped together and reduced to assumed real-world parameters. This means that the results obtained by applying this technique may not be representative for the real-world system if the model is incomplete or wrong. Therefore, having a good understanding of the system or the problem to be solved is paramount in the process of searching or developing an appropriate technique or approach that will enable a solution for the real-world problem to be reached.

As the optimisation route is currently infeasible, because the criteria necessary to apply this approach cannot be met other approaches must be considered. As such, to identify the gaps, or where research is needed and efforts should be focused, the following research topics were set to be investigated:

1) The challenges in selecting training media to construct pilot training programmes
2) The needs of the decision-makers

By investigating the above topics, specific issues related to the selection of media for construction of training programmes are identified and the research questions addressed in the rest of the PhD project are defined. To identify a suitable research approach to support this process, extant research approaches, philosophies and methodologies have been explored for suitability. These are presented in the following section together with the rational to eliminate or endorse them.

1.2 Problem space

To investigate the research topics set in subsection 1.1.4 Project aim ("The challenges in selecting training media to construct pilot training programmes" and "The needs of the decision-makers") relevant literature concerning the subject matter and discussions with decision-makers have been conducted in the preliminary phase of this research project. The investigations and the results are presented in this section as follows: Subsection 1.2.1 Constructing training programmes for UK pilots, looks at how UK pilot training programmes are constructed while section 1.2.2 Extant approaches and tools for training media selection, looks at the current knowledge regarding the selection of media for training construction. Finally, in section 1.2.3 Industry needs, the investigation on what the issues and needs are from the industry point of view (i.e. from the point of view of the trainers, designers and managers of pilot training programmes).

1.2.1 Constructing Training Programmes for UK Pilots

Training programmes for military aircrew training, over the years, have been designed, developed and adapted according to requirements, standards and military doctrine, available resources and knowledge of the time. For example, the fast-jet training programmes evolved from putting men almost directly into the aircraft and sending them on military missions (learning on the job) to nowadays to using sophisticated simulators and equipment to learn and exercise various flight manoeuvres before progressing to airborne training and further to front line operations (Shank et al., 2002).

Currently, the UK's fast-jet military pilot training comprises the following stages: Elementary Flying Training (EFT), Basic Flight Training (BFT), Advanced Flight Training (AFT) and Operational Conversion Unit (OCU). At the end of OCU the pilot will be classified as Limited Combat Ready (LCR) and following the Front-Line (FL) training the pilot will be considered as being Combat Ready (CR). The most advanced stage in the training of a fast-jet pilot is the Mission Training (MT). When at this stage in training, pilots learn and rehearse various knowledge, skills and attitudes specific to operational scenarios. The first stages of the aircrew training involve more the acquisition of skills and knowledge related to general flying procedures while the later stages involve more the acquisition of skills and knowledge related to problem solving and decision-making in complex, operational-like situations. These stages are presented in Figure 1.2. For more details regarding the UK RAF military aircrew training, the RAF Flying Training Pipeline Pilot Branch Overview and the RAF Flying Training Pipeline for Fast-Jet Pilot Stream are presented in Appendix 1.

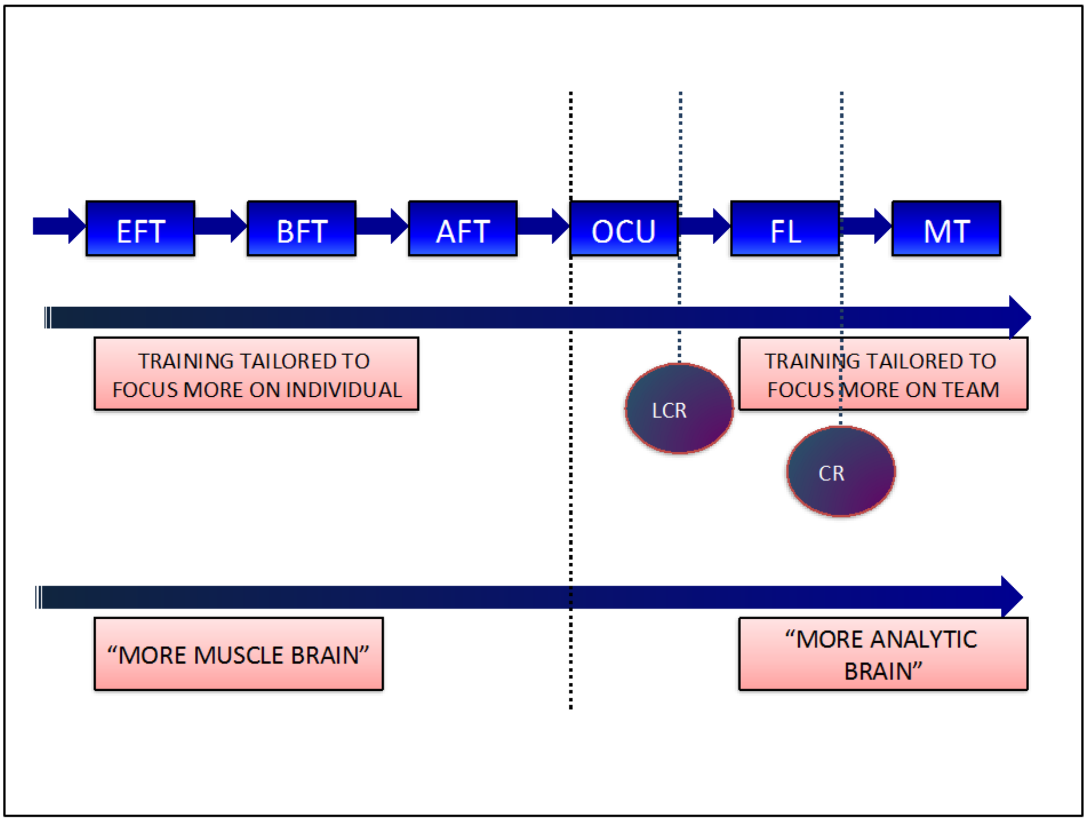

Figure 1.2 The fast-jet pilot training programme pipeline

The fast-jet pilot training is constructed in a streamlined manner, with the pilots needing to complete the preliminary phases in order to progress to the following ones. A formal assessment takes place at the end/beginning of each phase and as a result of these assessments, pilots are promoted, distributed, redistributed or failed from the programme.

In 2012, the National Audit Office (NAO) identified that there is a £38 billion funding gap in the ten-year Defence budget announced in 2010 (NAO, 2012). Furthermore, when looking at the Typhoon Project, NAO identified two main risks related to training that will affect the delivery of the Typhoon capability, the limited flying hours and the availability of synthetic training devices. Therefore, it is suggested in the report, that to address the identified risks, the Ministry of Defence (MOD) needs to find cost-effective and innovative ways to design and provide the training (NAO, 2011). This contributes to the importance of research that could provide solutions that could aid the effort of constructing flexible, safe and resource-efficient training programmes.

The MOD does provide guidelines regarding the design, development and delivery of training within the Defence sector. These guidelines are encapsulated in a joint[1] policy document, the *"Joint Service Publication (JSP) 822 – Governance and management of defence individual training, education and skills"* and covers aspects related to the governance, management and delivery of training and education (JSP822, 2014).

In the JSP 822 (2008)[2] is provided a framework for organising and controlling the design, development and delivery of training through a systematic process. The process was developed based on systems approach and comprises four main stages:

- Needs Analysis
- Training Design & Development
- Training Delivery
- and Evaluation, which is applied to all previous stages

[1]Joint refers to tri-service; air, sea and land
[2] The difference in referenced years is because the document is an online repository and the chapters of the document are updated at different times.

This framework however is just a guideline and it is up to the providers of training (which can be organisations outside the MOD) how the framework is utilised (JSP822, 2008). The Defence Systems Approach to Training (DSAT) Process as it appears in JSP 822 is presented in Figure 1.3.

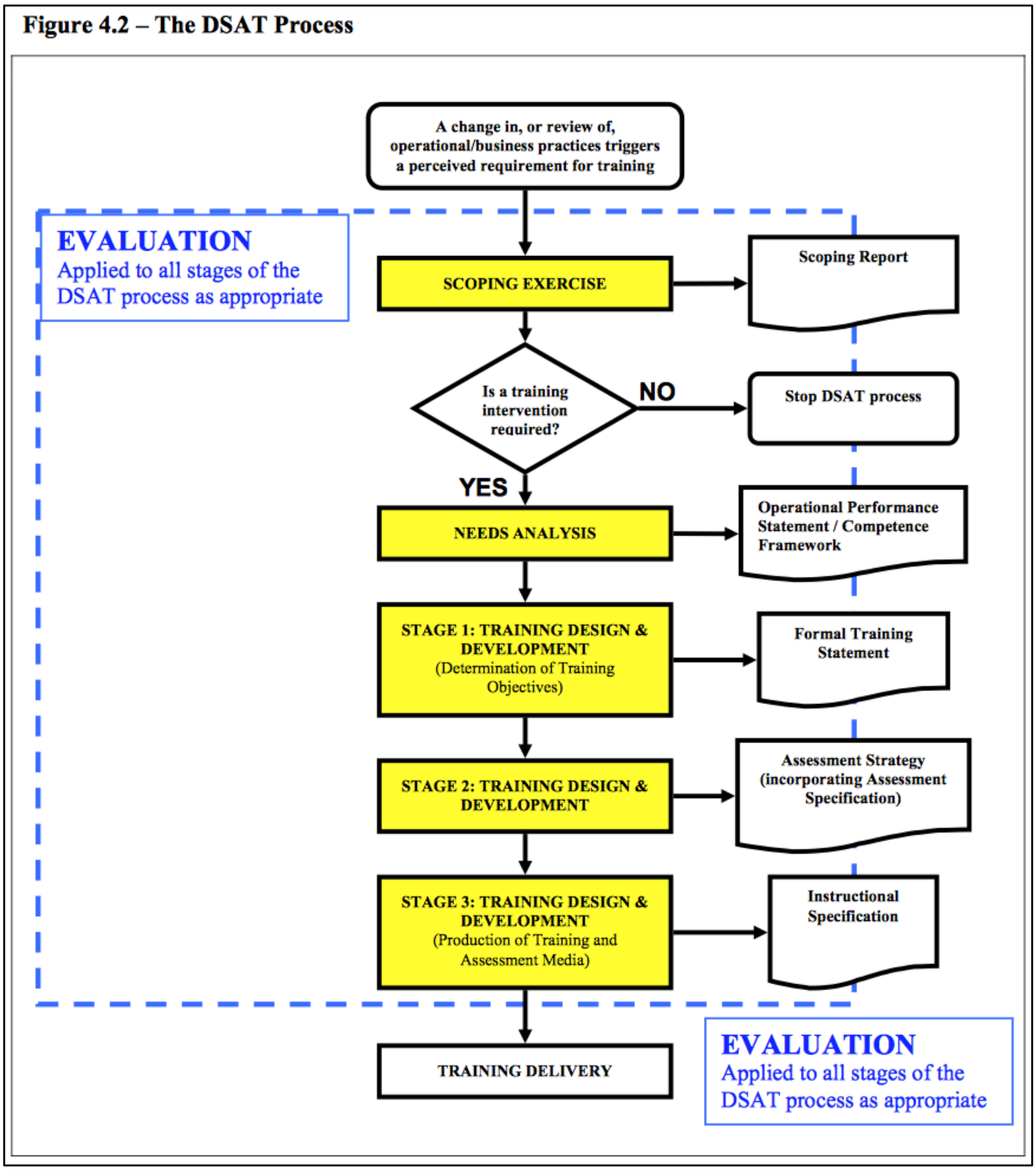

Figure 1.3 DSAT Process (MOD, 2008)

Figure 1.3 shows that the 'Production of Training and Assessment Media' task is included within Stage 3 ('Training Design and Development) activity. However, in the JSP 822 it is also stated that *"The outcome of the training needs analysis is defined as the training needs to be addressed and the most cost-effective means to achieve them"* (MOD, 2008) during the 'Needs Analysis' Stage. The 'Needs Analysis' phase however is a stage that takes place prior to the ‘Training Design & Development’ one. Furthermore, within the ‘Training Design and Development’ phase of the DSAT Process it is stated in the JSP822 that the ‘Selection of Methods and Media’ activity should happen at this stage.

As can be observed, within the MOD DSAT Process there are two references in regards with training method and media selection to construct training programmes. One selection activity happens at the beginning of the process, following the ‘Needs Analysis’ Stage and another selection at the end of the process, in Stage 3 (‘Training Design and Development’). This suggest that the decisions made regarding the selection of training media are done at two levels: first, at a higher analytical level (analysis) and second at a more detailed, technical level (design). This has implications for the development of any approach and/or tool for media selection as the requirements for selection may be different, depending on the stage of selection.

1.2.2 Extant approaches and tools for training media selection

The problem of selecting media for training is not a new one. Over the years, researchers have developed various approaches and tools to answer or provide support in solving this problem. However, so far, little evidence was found of any of them being widely endorsed. Furthermore, little to no evidence of published research was found to be available for some of the most recently developed ones (e.g. ADVISIOR; MMST[3]).

One reason for the lack of publicly available evidence might be that the tools are developed by companies (e.g. ADVISOR by BNH Expert Software; MMST by SIMUL8 Corporation) and used by state intuitions (e.g. MMST used by MOD) and there are restrictions over commercial rights and/or security concerns. However, in the case of the published tools and approaches, the lack of wide use prompted the question of ‘Why they have not been endorsed in practice?’ and the need to have a closer look at the research so that the problem area that this research is addressing could be fully understood and lessons learned.

[3]MMST = Method and Media Selection Tool

In this section, a series of approaches and tools are going to be discussed. They will be presented individually and in a chronological order to highlight their evolution over time.

"Media Selection for Training" – Sugrue and Clark 2000

More than a decade ago, Sugrue and Clark (2000) developed a paper-based systematic approach to media selection based on the cognitive components of learning and instructions. The approach comprises three sequential stages:

1. Selection of instructional method
2. Selection of media attributes
3. Selection of media for training

Sugrue and Clark (2000) approach for media selection is focused on the function of training, which is defined in terms of the cognitive components of learning that the training supports. One main benefit of this approach is that it offers a thorough method through which decisions can be traced and justified and is focused on the cognitive component of learning and instructional process, which are the essential components in any training programme. However, as the authors themselves state, the process of applying this method is laborious and the end result provided by using it is rather intuitive and therefore, perhaps faster to be reached by experts without the use of the approach. Furthermore, they acknowledge that the decision-making problem context, the educational situation, is complex and that the decision to be made is based on a large list of potential factors, which may not all be accounted for.

Sugrue and Clark (2000) also draw attention that the cognitive process of learning that their approach is based on, is dynamic and continuous by nature, and these characteristics have a direct impact on the way in which instructional methods are selected and subsequently on the selection of media to support the delivery of those methods. Another important factor that is mentioned in Sugrue and Clark (2000) paper is that the choice of media depends on the media itself as well, i.e. on the available media options; and the challenge here is that these options change as technology develops (e.g. more versions of the same software program becomes available). Sugrue and Clark (2000) critique previous methods of media selection stating that they became redundant as media for training developed, which poses the question, if not any developed method or tool becomes redundant sooner rather than later as technology develops at quite a fast pace?

Making the assumption that technology will continue to develop and that the number of training media options will continue to increase, it could be concluded that any new developed tool or approach to support the selection of media for training should be robust enough to account for these variations in order to be fit for purpose. Perhaps, to account for these variations, such as the continuous developments in technology and the continuous and dynamic character of the learning process, it would be useful to explore other approaches.

Sugrue and Clark (2000) in their paper make another important point that sits perhaps at the core of considering developing any new approach and tool designed to support the selection of media for training, and that is, that the selection of media for training very much depends on the selection of method for training. This relationship between media and method however is not a simple one. For two decades now, this relationship has been the subject of an extended debate in the literature where on one side there are researchers (e.g. Clark) that take the standpoint that media does not influence learning[4] and on the other side researchers (e.g. Kozma) that consider that media does influence the learning process.

Sugrue and Clark (2000) position on the debate is that media does not have a direct impact on the learning process and that the media role is to offer support to deliver the method; hence the stages of the approach to media selection that they propose. Method on the other hand is regarded as being that component of the training that directly affects the learning process.

"Training Needs Analysis for Team and Collective Training" – Pike and Huddlestone (2011)

Ten years after Sugrue and Clark published their approach to media selection, Pike and Huddlestone (2011) developed a paper-based approach for media selection

[4] Learning it is not synonym with training however, it is the main goal/aim of training.

specific for aircrew training. Their approach is embedded within the Training Needs Analysis (TNA) process and is focused on supporting decision makers to construct programmes/exercises[5] for teams and collective training. Pike and Huddlestone (2011) approach to media selection consists of three consecutive stages:

1. Identification of requirements for training media environments
2. Identification of media environment options
3. Selection of media environment

Pike and Huddlestone focus on the analytical stage of media selection and look at media as being the environment in which training takes place. As such, they view the training environments as being either live (real people operating real equipment in live situations) or simulation. In terms of simulation Pike and Huddlestone (2011) differentiate between eight types of environments:

- Virtual simulation – *"real people operating simulated equipment in virtual environment"*
- Constructive simulation – *"real people exercising military decisions on the basis of information constructed by a computer system"*
- Live simulation – *"real people operating real equipment with simulated effects in a live environment"*
- Embedded simulation – incorporation of simulated capability into operational equipment (e.g. simulation modes build into warfare systems)
- Network simulation – the networking together of multiple simulators
- Distributed simulation – the networking of simulators and simulator networks across different sites
- Synthetic Wrap – combination of the use of live and virtual simulation
- Augmented reality – the integration of synthetic elements into live environments (e.g. false targets into weapon display)

For full breakdown of simulation environments see Appendix 2.

[5] The terms "training programme", "training exercise" and "training event" are used interchangeably throughout the thesis as training is taken as being a unit, regardless of the magnitude.

While the first four (virtual, constructive, live and embedded) and the last two types of simulation training environments (synthetic wrap and augmented reality) do differentiate to a certain extent, i.e. from the point of view of type of media used, the networked and distributed simulation differ from the point of view of type of connectivity and location of devices and not type of media. One criticism that could be pertinent in this case is that the differentiation between these categories of environments is not made on the same principle. For example, it is not clear from the authors' definitions what is the difference between embedded simulation and augmented reality or that networked and/or distributed simulation is something different than virtual simulation or any other type of simulation.

Overall, Pike and Huddlestone (2011) approach is focused on comparison of the technical capabilities of alternative environment options based on the requirements resulting from the TNA analysis and this is one main benefit that this approach offers; that of connecting the selection of media with the training objectives (the analytic with the technical). Their approach also takes into consideration the selection of method prior to that of selecting the media, the same as the approach proposed by Sugrue and Clark (2000). Pike and Huddlestone consider this step 'Selection of method for training', as being part of the first stage in the approach, 'Identification of requirements for training media environments' alongside identification of training tasks.

Although the approach is recommended as a way to evaluate the technical aspects of effectiveness of the training media environments, Pike and Huddlestone (2011) draw attention that assessing the overall effectiveness of the training media environment options is still a *"difficult and subjective task"* (p.114). No evidence regarding the effectiveness of this approach or comparison studies with other approaches were found in the literature.

ADVISOR Enterprise – BNH Expert Software (www.bnhexpertsoft.com) 2007-2013

ADVISOR is a web-based decision-support tool designed by BNH Expert Software Company to analyse training needs, forecast and optimise training resources, allocate resources and provide an audit trail to support recommendations. The tool is divided into five modules: training analysis, training design, resource management, project management and performance analysis; each module being able to be used separately or together, depending on the needs of the user.

In a white paper published by Bahlis, on the BNH Expert Software website (www.bnhexpertsoft.com) a seven step process is presented that the ADVISOR tool uses for analysing a training course to determine the most economical blend of delivery methods (such as: instructor led, print, tapes, computer based, web based, computer, Internet) to meet the training needs. These are:

1. List Instructional Goals and Group Goals into Instruction Modules
2. Evaluate Effectiveness of the Plausible Delivery Options
3. Estimate Development Time
4. Compute Direct and Indirect Costs
5. Rate Plausible Delivery Options
6. Assess Risk and Compute Hidden Costs
7. Determine the Right Blend of Delivery Options

Unlike the approaches presented so far, the ADVISIOR tool has quite an impressive record of being used. Melton and Bahlis (2013) ‘ADVISOR Enterprise Media Selection Model Fact Sheet’ offers a list of organisations that either use, recommended or reference the use of the tool. This list includes mainly defence sector organisations (like US and Canada defence ministers). Furthermore, Melton and Bahlis (2013) offer a comparison analysis with other existing models and they point out that compared with other tools and approaches, ADVISOR offers an automated selection based on collected data to rank recommended media and provides a list of requirements that the media under consideration does not meet. In addition, while other models only suggest that the cost associated with media are important and need calculating, the ADVISOR model actually provides an analysis of the costs by automatically calculating the estimated costs for the media options based on user input, allows comparison of the costs of various options, calculates the projected return of investment (ROI) and displays the results (Melton and Bahlis, 2013).

While the benefits and plus points that this model of media selection for training offers when compared to other tools are quite clear, what is less understood from the information found is how effective this tool is. Furthermore, the model does not offer an answer to the objectivity issue, i.e. the inputs which the tool makes the analyses and calculations on are based on subjective user input such as responses to questions, which begs the question of how objective are actually the answers that the tool provides.

As with the approaches mentioned before, the ADVISOR tool developers see media as being "delivery methods". Furthermore, they encapsulate under the term of 'delivery methods' a variety of examples ranging from "instructor led" to "computer". The complete classification of training media that the ADVISOR tool uses is shown in Appendix 3.

It can be argued though that these 'delivery methods' could be understood either as method, or media, or as a combined construct of media and method. For example, if we take the "computer", on its own it is just a medium, a tool. When combined with some instruction of operation/use however it becomes a way, a method of doing something supported through "computer" as the tool. The aspect of how media and method is understood is important in the way we analyse the effect that media and method has on the overall learning process. Regarding media, Bahlis view is that as long as the instructional methods are supported by the delivery methods and the learning environment is adequate then the impact of the delivery methods on the learning outcome is going to be minimal.

Overall, the ADVISOR tool is a well-designed system that can offer valuable support to decision makers in constructing training programmes not only through the analyses and calculations that are made but also through the fact that it documents and stores the information, offering an audit trail for the decisions made. However, one could still question the objectivity of the answers that the tool provides as the input information (except costs) are based on the subjective judgement of the user.

Method and Media Selection Tool (MMST) – JSP822(2012)

The MMST is a web-based tool developed to provide support for decision-making when optimising learning. The tool user manual is presented in the MOD JSP822 (2012) which recommends that the MMST to be utilised as a reference tool to support working group discussions between various SMEs such as training specialist, course designers and sponsors (JSP822 – Part 5, Chapter 7, 2012).

The MMST is part of a wider process provided by the MOD, Defence training and education, to guide the construction and delivery of training programmes for the defence sector (Fig. 1.3: DSAT process). The MMST provides a simple and fast framework to analyse and select training methods and media options at a basic level before starting the process of developing or procuring learning technologies for training.

The approach is divided in a two-stage selection process:

1. Method Selection Tool
2. Media Selection Tool

The first “Method Selection Tool” is concerned with the selection of a mix of methods to train based on learning requirements. The learning requirements are introduced in the MMST through the following process: tool users are required to select the percentages for each requirement based on their importance (e.g. 80% physical skills and 0% attitude skills) by sliding a cursor on a continuum. The tool then outputs a chart showing a mix of methods to be employed and indicate an initial cost per student/per hour. The methods in the mix are shown depending upon the weight they bare in achieving the learning requirements (e.g. practical lesson 50%, tutorial 30%, simulation 10% and self-study 10%) and the costs are based on instructors rate and initial set up costs (JSP822, 2012).

In the second stage, “Media selection Tool”, each method selected in the mix that requires technological support, such as ‘simulation’ is put forward for further analysis. The tool users are required to slide the cursor over each category of training requirement and then a graphical output is generated by the tool showing a mix of media recommended to be used to deliver that method. This process is similar with the one followed to choose the mix of methods however, in the case of the media mix only one or two media (those with higher scores) are recommended to be implemented not the whole blend of media, as it is the case for methods (JSP822, 2012).

Conclusions of survey on extant approaches and tools for training media selection

The surveyed approaches and tools display similar characteristics in terms of the approach towards media selection, that of selecting the training methods prior to selection of media. Furthermore, in terms of separation between method and media as well as differentiation between different types and instances of training media, the survey shows that there are confounding boundaries when it comes to differentiating between them.

Another similarity between the considered approaches and tools was that they all consider roughly the same factors as the starting point of the analysis; these are the training tasks and the cognitive characteristics of the tasks, i.e. how much and what type of cognitive effort is required. These are further considered to be requirements for selection of methods of training and subsequently for selection of training media.

However there are some differences between the tools and approaches. Some, such as Sugrue and Clark’s (2000) and MMST (2012) concentrate more on the cognitive characteristics of tasks while Pike and Huddlestone’s (2011) concentrate more on physical characteristics of the tasks.

One other important feature that differentiates the surveyed approaches and tools is that some are paper-based while others are computer-based. This feature appears to have implications in terms of decision-making efficiency. The paper based approaches are much more laborious than the computer-based ones and since the amount of information required to be considered when selecting media for training is quite complex and possibly very large, it could be sensible considering developing computer-based solutions to support this decision-making activity rather than paper-based ones.

1.2.3 Industry needs

In this section the views of the industry regarding selection of media to construct training programmes as well as the stakeholders’ requirements for the development of an approach to support the selection of media for constructing UK pilot training programmes are going to be presented. The purpose of this step in the research is to explore the from a practical point of view the problem space and identify gaps where research is needed, as well as to gather information that will guide the development of support solutions.

This section is split into two main parts: ‘Industry Perspective’ and ‘Needs and requirements’. Though both parts contribute in equal measure to the identification of areas where research is needed, the focus of the investigations is different. In the first part, “Industry perspective – a case study”, the view and practice of industry regarding selection of media to construct training programmes in general is investigated, while in the second, “Needs and requirements”, the view of the industry regarding the development of specific solutions to support the selection of media to construct training programmes is considered. The conclusions of these investigations are presented at the end of the section.

Industry Perspective – a case study

A series of meetings with SMEs, one-to-one discussions and focus groups, as well as an observation of the delivery of a training exercise in a synthetic environment have been conducted to obtain ‘as is’ information regarding the construction of pilot training programmes. Furthermore, industry documents specifically related to the selection of media to construct pilot training programmes have been analysed.

The purpose of this inquiry was to understand the environment and identify current issues surrounding the subject under investigation. Furthermore, the results of this particular phase of research were used to guide the following research phase, requirements elicitation and further, in the development of support solutions. The rational for the chosen method of enquire and description of how the data was collected and analysed is presented in Chapter 2: Methodology.

Results and discussions

In this section the results of the case study are presented. The findings are supported by quotations from the interview notes and extracts from reviewed document.

Following the analysis of data it was found that:

Training programmes are usually constructed on a *"case by case"* basis:

> *"make stuff as you go"*

> *"9 out of 10 occasions training needs tailoring due to increase complexity and changing requirements"*

> *"new requirements are accommodated on a come and served basis"*

> *"training tasks change more often than any other variable"*

Training programmes construction depends on three main factors: training needs, training audience and resources

> *"it starts from the training needs then the audience and the existing resources are looking at; if resources are not adequate then that triggers the acquisition of new resources process"*

However, when it comes to lower level factors that influence the construction of training programmes there was reported that there is *"difficulty in understanding the relevance of many of the variables"* and *"often there is not a direct link or knowledge exist to assign values to variables"*. Some of the reasons are captured in the following extracts:

> "*assigning a value to a degree of difficulty of the environment required cannot be done in absolute terms; a mountainous terrain environment may make a specific task much harder but in a different scenario could make it much easier*"

> "*determining the optimum number of hostile aircrafts for the best learning opportunity for a specific skill is not realistic, there are so many dependencies that a direct correlation was not thought to be possible* "

> "*the application of the influence of the various Threat levels is too simplistic. It was not possible to determine a simple relationship between the Threat level of the hostile aircraft and improvement or otherwise in a skill*"

> "*in many circumstances it wouldn't be beneficial to fix variables from the outset as these will change according to the requirements of the training event. For example, specifying a certain level of granted flexibility wouldn't be normally done in advance; instructors would want to vary this according to the needs of the student or the training exercise as circumstances develop*"

Furthermore, it was reported that "*an enormous amount of subjectivity is required to assign values to the variables*" and given the lack of experience on all or new LVC training systems "*even the quality of the subjectivity is questionable*". The subjectivity involved in the construction and assessment of training was quite evident from the participants account:

> "*decision making is based heavily on experience*"

> "*benefits of exercise assessed by getting feedback from front-line commanders*"

> "*military SMEs specify the layout of simulation*"

> "*complexity of simulation is based on SMEs judgement*"

> "*assessment of training programmes are made based on expert opinion, scoring matrix to meet requirements and trade studies*"

Although as part of the assessment of training programmes a scoring matrix to meet requirements is used, it was found that there is no quantifiable form of how training requirements are followed.

> "*although everybody needs to meet the standards and follow the requirements, from squadron to squadron there are differences in training and therefore their abilities*"

Overall, it was found that there is a lack of formal processes and objective evidence on the basis of which to assess the utility of training programmes. For example, one of the SME stated that there is

> "*no formal process to assess the utility of training exercises*".

Training requirements are the starting point of any process of constructing training programmes however, the representation and transfer of these requirements to the following activities, involved in training programmes construction, seem to be problematic; it was reported that

> "*there is a communication gap between requirements generation and design of training* "

Furthermore, it was found that the training needs analysis, which delivers the training requirements is not a uniform process:

> "*there is no formal way of doing TNA for joint or international training exercises, everybody makes their own TNA and then who is leading the exercise adapts and integrate the training needs*"

Regarding the factors, that influence the construction of training programmes that are related specifically to the trainees it was found that existing competencies breakdowns, such as MECs[6], are problematic:

> MECs "*are a curious mix of the highly specific to very broad and high level. For example, 'formation region' is a very specific, manual task whereas, 'develop new option' is a much higher level function. Attempting to assign values to variables proved impossible given the lack of uniformity between the levels of types of skills*"

Furthermore, it was reported by the participants that trainees' previous experiences and 'special events' during training have a higher impact on trainees' readiness and overall abilities than trainees' personality and individual learning styles, especially in the later phases of the training pipeline (Figure 1.2):

> "*pilots have been through different learning styles by now, they are adapted*"

[6] Mission Essential Competencies

"*not important towards the end of the training as pilots are used to different teaching styles*"

"*trainees previous experience may have a bigger impact" and "more focus is needed on trying to measure and capture this*"

"*special events influence pilot performance*"

Analysis of the data revealed also that there is an issue with assessing and selecting training media equipment to construct training programmes because:

"*data concerning training equipment is more difficult to get because of associated commercial complexity*"

"*use of definition is problematic*"

"*synthetic training contains live training elements*"

"*more research needed on live-synthetic integration*"

"*training systems created*" for a training exercise *"are used only for one programme*"

Summary of results and conclusions

The purpose of this part of research was to explore the problem space and investigate the process of constructing training programmes. Within this phase of research twenty SME's were interviewed in a series of focus-groups. In addition, data were collected from observing the delivery of a training programme (an Apache Helicopter attack training exercise) and review of industry documents.

Results showed that the construction of training programmes is based on three main elements:

- training needs,
- audience characteristics and
- resources

Furthermore, training programmes are usually constructed on a case-by-case basis and a cause of this might be that the training requirements change more often than any other variable.

Training requirements are the starting point of any process of constructing training programmes. However, it was found that there is an issue with communicating these across other training construction phases, such as to the training design team. Furthermore, the process of training requirements generation does not seem to be a uniform process and that everyone does "*their own analysis*". This may hinder the situational awareness of decision makers regarding the totality of factors that affect the selection of media and construction of training programmes.

It was also found that some of the variables on which the decision to select the optimum set of components to construct training programmes relies on variables that are difficult to quantify and therefore it is hard to understand the impact that these have on the outcome of the training. This also impacts the decision makers' awareness.

Furthermore, results showed that there are a couple of issues regarding training media devices that need to be selected to construct training programmes. There is a lack of clear boundaries and definitions between the training media systems and understanding of the impact that they might have on the training, especially when they are integrated with other systems to construct a training programme. As a result of the lack of understanding of new training media equipment, training systems created for one training programme are not usually used for other training programmes.

Regarding the training audience, it was found that existing competency breakdowns, such as MECs are not fully comprehensive due to the level of breakdown and therefore difficult to integrate in training programme construction. Furthermore, SME's opinion is that trainee's personality and different learning style counts less in training programmes design for stages towards the end of the pilot training pipeline and that trainee's previous experience is a more important factor. Moreover, participants indicated that more focus is needed in trying to measure and capture these characteristics.

The findings show that overall, the construction of training programmes and assessment of their utility relies mainly on the subjective experience of SME's and that there is a lack of uniform procedures across the fast-jet pilot sector regarding construction and assessment of training programmes. Although the subjectivity of the process is not necessarily desirable, it is understandable given the underlying issues that this study revealed. It is clear that the decision makers do not have the necessary facilitators for a more objective decision to be made and therefore they must rely on their trusted experience.

Needs and requirements

In this section, the requirements for the development of solutions to support the decision-making activities to select training media to construct training programmes are going to be presented. The purpose of this part of research was to investigate and document specific customer needs regarding development of a support solution. Detailed information on the method used to collect and analyse the data is presented in Chapter 2: Methodology.

The investigation of the customer needs also contributes to the overall exploration and understanding of the problem area. The difference between the research presented in this later part of the chapter to that presented earlier is that the investigation moves its focus from general to more specific. While in the case study, the phenomenon of selecting training media to construct training programmes was investigated without a specific output in mind, in this part, requirements elicitation, the research is focused on gathering specific information related to developing support solutions.

This latter part of research (Needs and requirements) was built on the findings from the first (Industry perspective – a case study). For example, in the case study it was found that the subjective character of the decisions taken by decision-makers when constructing training programmes was mainly due to limited awareness regarding the information necessary for the decision (e.g. impact of various variables, i.e. new training media) and lack of decision-facilitative elements (e.g. requirements communication issues, issues with capturing and representing trainees' previous experience). Based on these findings, it was decided that further research in this project should focus on exploring the solution space to provide support for the construction of training programmes. Therefore, SMEs were interviewed with the specific purpose to elicit requirements for a decision-making support system.

Customer's needs and requirements

During the requirements analysis phase it became obvious that to design and develop a complete solution-system according to stakeholders' expectations more resources are needed, which were not available at the time when this research was carried out. As such, it was decided that research effort should not be spent on trying to develop a complete and comprehensive set of requirements and that the form of requirements, which can be summed up as customer needs and expectations in terms of required solution, is sufficient for the purpose of conducting the research in the framework discussed at the beginning of the thesis. Furthermore, the requirements were generated on the basis of the needs of the customer expressed in interviews and not on the basis of formal written requirements.

The gathered requirements were presented for review to BAE Systems' SMEs (who are considered to be 'the customer') and as a result, a list of 72 requirements was accepted. These are presented in Appendix 4.

To ease the understanding of the customer needs, the requirements have been grouped into themes and the themes into categories. These are presented in Table 1.1.

Category: Functional Requirements	

Theme: Must consider the Training Objectives (TOs)	• Should use as input the TOs.
	• TOs should be selected from a database.
	• Should provide a catalogue of training objectives.
	    o TOs should be split according to their characteristics.
	    o Should specify the physical characteristics of TOs.

Theme: Must consider the training media characteristics	• Should provide training media devices capability register (catalogue).
	    o The capability register should contain characteristics of devices.
	    o Training media characteristics should share same language.
	    o Training media devices should be broken down based on their functionalities.

	- Should have a library of training media devices functionalities. • Should provide information about training device safety.

Theme: Must assess the training media	• Should measure the training efficiency and effectiveness.
	• Should indicate the training value of training media devices.
	  o Should indicate the training value using Gagne's categories of learning outcomes.
	• Should assess training media.
	  o Should perform trade-off analysis between training media options given the training tasks.
	• Should consider ownership and IP rights of training media devices.
	• Should not assess media based on: schedule, cost, availability.

Theme: Must connect with other tools	• Should allow connection with tools that show schedule, costs, and availability of training media devices.

Theme: Must aid construction of training solutions	• Should help at determining the training solution.
	• Should aid decision-making.
	• Should not duplicate existing processes (in training programmes construction).
	• Should specify needed training media characteristics.
	• Should provide capabilities/functionality needed for training media devices.
	  o Should provide a summary of training media capabilities.
	    - Training media capabilities should be defined.
	• Should provide training media options.
	  o Should include training media weightings.
	  o Should provide description of training media options.
	    - Should contain information about the training devices.
	    - Should contain information about training media.
	    - Should contain information about knowledge and skills to be trained.
	  o Should provide definitions of media options.
	• Should specify training media devices needed to train a training objective.
	  o Should connect TOs with training technology.
	  o Should match training media characteristics with TOs characteristics.

<table>
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Should associate the training devices capabilities with TOs.
Should provide definitions of training devices.
Should provide interoperability information.
Should provide training’ devices manufacturer’s information.

Should specify training media blend for a training exercise.
Should provide information on training media devices’ integration.
Should aid the training design phase.
Should support Training Needs Analysis (TNA).
Should connect the training requirements (TNA output) with the training environment development process (Design).
Should indicate the training environment complexity level needed.
Should specify training media components rather than training media systems.

</td></tr>
<tr><td colspan="2">Category: Technical Requirements</td></tr>
<tr><td colspan="2">

TOs database should be updatable.
Training devices capability register should be updatable.
Should trace the decisions made.
Should document any changes made.

Should document who did the changes.
Should document when a change was done.
Should document what change was done.

Should allow changes done only by ‘central’.
Should have a single domain user.
Should not duplicate information.
Should have open architecture.
Should have modular and generic architecture.
Should be distributive.
Should have black box.
Should store the outputs.
Should lock down the output.
Should be consistent and lock down for standardisation.
Should be updatable.
Should be able to be linked with other systems.
Should have XML structure.

</td></tr>
</table>

Table 1.1 Requirements for development of a system to support decision-makers in constructing training programmes

To support the definition of research questions the customer needs presented in Table 1.1 were further clustered in four categories:

- The need for a supporting link in transferring the training requirements from the analytic (TNA) phase to the Design phase of training construction
- The need to support the training programmes to be tailored for specific pilot needs
- The need to support the assessment and selection of training media
- The need to support the connections between training methods and training media

Conclusions of investigation of industry's perspective on the problem space

This section has presented the research that was undertaken with the scope of exploring problem space from an industry point of view and to gather information that will guide the development of the solution.

The results showed that overall, the construction of training programmes relies mainly on SME's subjective judgement and that there is a lack of uniform processes across the UK pilot training programmes to construct and assess training media option and that the decisions are mainly based on the subjective opinion of experts. From the findings it became clear that the subjective character of the decisions is mainly due to the limited awareness that decision-makers have when it comes to the information necessary to make the decisions and the lack of sufficient decision-facilitative elements (such as tools, processes, etc.) to help to process and access the needed information.

1.3 Research Questions and Outputs

This project was created with the aim of developing an approach with a support framework or tool through which the selection of media could be optimised; the purpose of the developed solution being to support construction of UK pilot training programmes.

Initial investigation of literature, i.e. on optimisation and Whittle and Valiusaityte (2010) study, showed that there are a series of conditions that need to be satisfied. Developing a support system to optimise a decision-making problem implies that that there is enough knowledge about that problem such that, a complete and accurate model can be built, to which an optimisation technique could then be applied. Having a good understanding of the system to optimise, or of the problem to be solved, therefore is paramount in the process of developing an appropriate approach that will enable a solution for the problem to be reached.

Given the issues with the optimisation route it was decided that a different research approach should be followed. Furthermore, it was decided that is important that the chosen approach should allow exploration of the decision-making problem of media selection for constructing training programmes as one of the main issues recorded was the lack of sufficient knowledge on this problem area (as discussed in section 1.1 Project background).

To summarise, research into the problem area of media section for construction of training programmes showed that:

- Determining values to assign to the various variables is challenging, the main reason being that no simple or direct correlations between specific skills and the linked variables can be found.
- The decision-making problem lacks structure, has a high degree of complexity and there are challenges in identifying and quantifying all the possible variables upon which the decision-making relies.
- The decision-making problem of selecting media to provide an optimal training regime is greatly context dependent and all properties are extremely coupled.
- The selection of media for training within the context of pilot training construction happens at two levels: analytical (TNA) and technical (System Design) – as showed by the DSAT process framework (Figure 1.3).
- The decision-making problem context from the point of view of the educational situation is complex and the decisions made are based on a large list of potential factors.
- Selection of media depends on selection of method; however, the relationship between method and media and their impact on learning is not a simple one.
- Synthetic training solutions such as Virtual and Constructive media have been steadily developed and introduced in pilot training as a practical and safe

alternative to live training, to rehearse typical tasks in operational scenarios. However, there are issues in differentiating between various types of training media and sometimes even between media and method, particularly when it comes to new technology.

- Assessing effectiveness of media in training is still a complex and subjective task.

Furthermore, results of the explorative case study showed that the following are the issues that the decision-makers face when selecting training media to construct training programmes:

- The decision-making is based heavily on subjective judgement.
- The decision-making is impacted by the decision-maker's knowledge of the decision-making problem, which often is incomplete.
- There are issues in communicating the training requirements from the analytic phase to the design phase of the training programmes.
- Training requirements management varies from service to service.
- The impact that some of the variables have on the outcome of training is not well understood.
- There is lack of clear boundaries and definitions when it comes to training media and lack of understanding of the impact that media might have on training, especially when used in combination with other training media.
- Trainees' experience is viewed by SMEs as being a more important factor that trainees' personality or preferred learning style.

The analysis of the customer's showed that the decision-makers need:

- A way to support the transfer of training requirements from the analytic phase (TNA) to the technical phase (System Design)
- Support for tailoring training not only on operational requirements but also on trainees' characteristics.
- Support in the assessment and selection of media for training.
- Support the connection between training methods (learning activity components) and choice of media.

As can be noted from the issues summarised above, the problem of selection of training media is not confined solely to the issue of differentiating, quantifying and measuring training media but it is tightly coupled with issues that had to do with management of training requirements, selection of training methods and trainees competences focused training. As such, the questions to be answered by this research were set as follows:

1) How can training media be differentiated? (set as there is a clear need to understand the differences between various training media to be able to start comparison between training media)
2) What is the role of media and method in training? (set as there is a need for more research into how media and method influence the learning process and each other; i.e. confounding boundaries)
3) How can the differences between trainees’ previous experiences be identified? (set as there is demand for more targeted, tailored training)
4) How can TNA information be managed? (set as there is a pressing issue of training requirements communication and/or transfer from the analytic phase of training programme construction to the design phase)

Following the exploration of the problem space and definition of research questions, the research effort was directed towards answering the research questions. Relevant literature showcasing research to date on classification of training media, the relationship between training media, learning and training methods as well as literature on assessment of trainees’ competences, Decision Support System and management of information has been investigated. This is presented in Chapter 3: Literature review.

Following, a set of solutions to support decision-makers in differentiating between training media, assessing trainees’ competences, manage training requirements and to foster further understanding of the relationship between media, method and trainee have been developed. These are summarised in Table 1.5 and presented in Chapter 4: Research outputs and developments.

Research questions	Research outputs
1) How can training media be differentiated?	**Training media – Classification Framework**; *a multidimensional classification framework to support classification of training media.*
2) What is the role of media and method in training?	A series of **models that map the relationship between media, method and learner,** based on which a **strategy towards training media selection** and a **framework for selection of Instructional process** was proposed.
3) How can the differences between trainees' previous experiences be identified?	**Trainees Contextual Proficiency Profile (TCPP)** – *concept (computer-based) tool developed to map and visualise trainees' gaps in skills and knowledge*
4) How can TNA information be managed?	**TNA output Analysis (ToA)** – *concept (computer-based) tool developed to manage and present in a graphical way TNA information.*

Table 1.2 Research outputs

The proposed solutions (Table 1.2) are at different stages of development, as such they vary from mere models that map various connections (e.g. Media-Learner-Method Cognitive Model) to concept tools (e.g. TCPP and ToA) ready to be developed and implemented. The place of the developed solutions within the problem space (Figure 1.4) that this PhD research is focused on is illustrated in Figure 1.5.

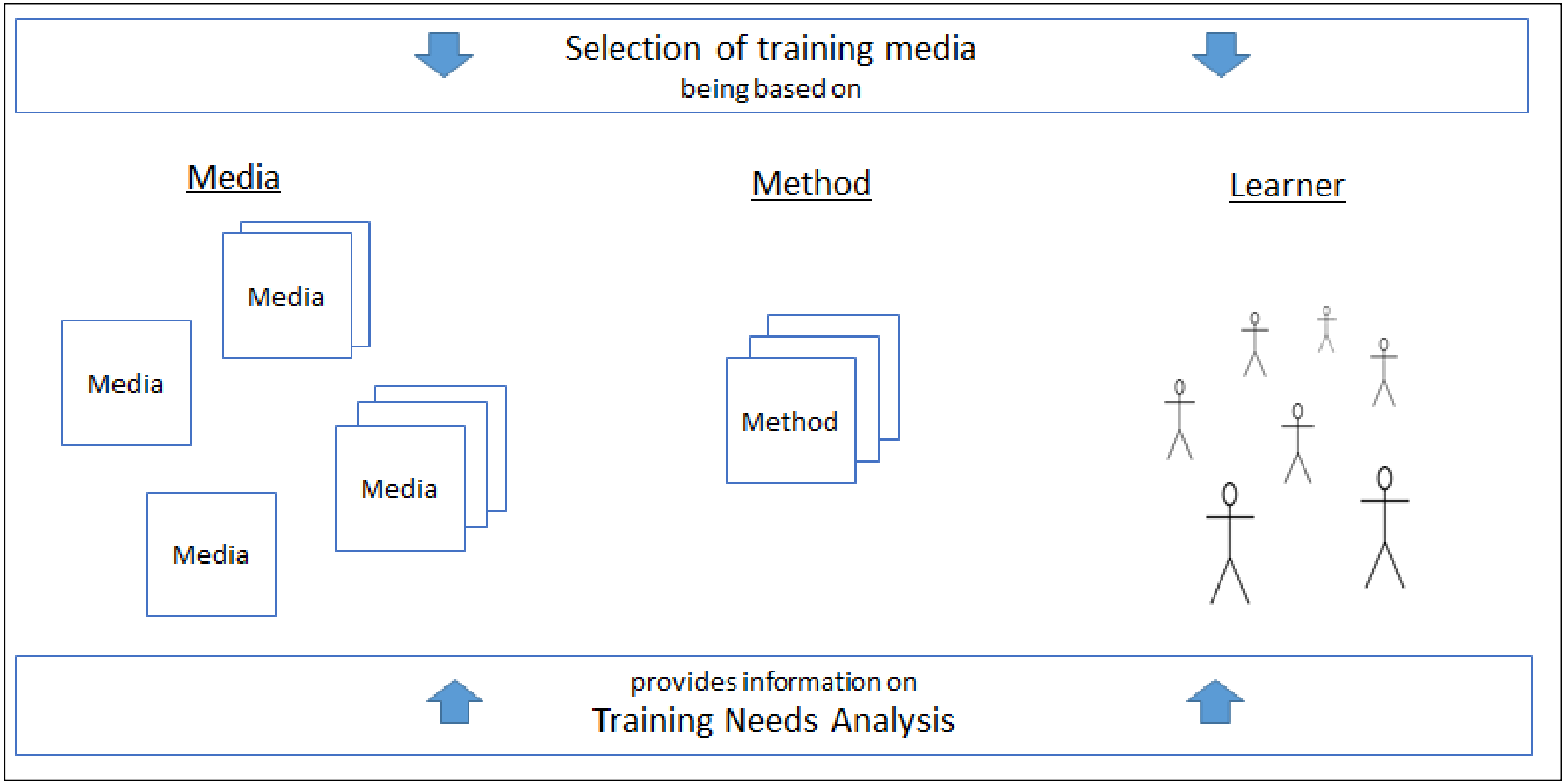

Figure 1.4 Diagram illustrating the problem space

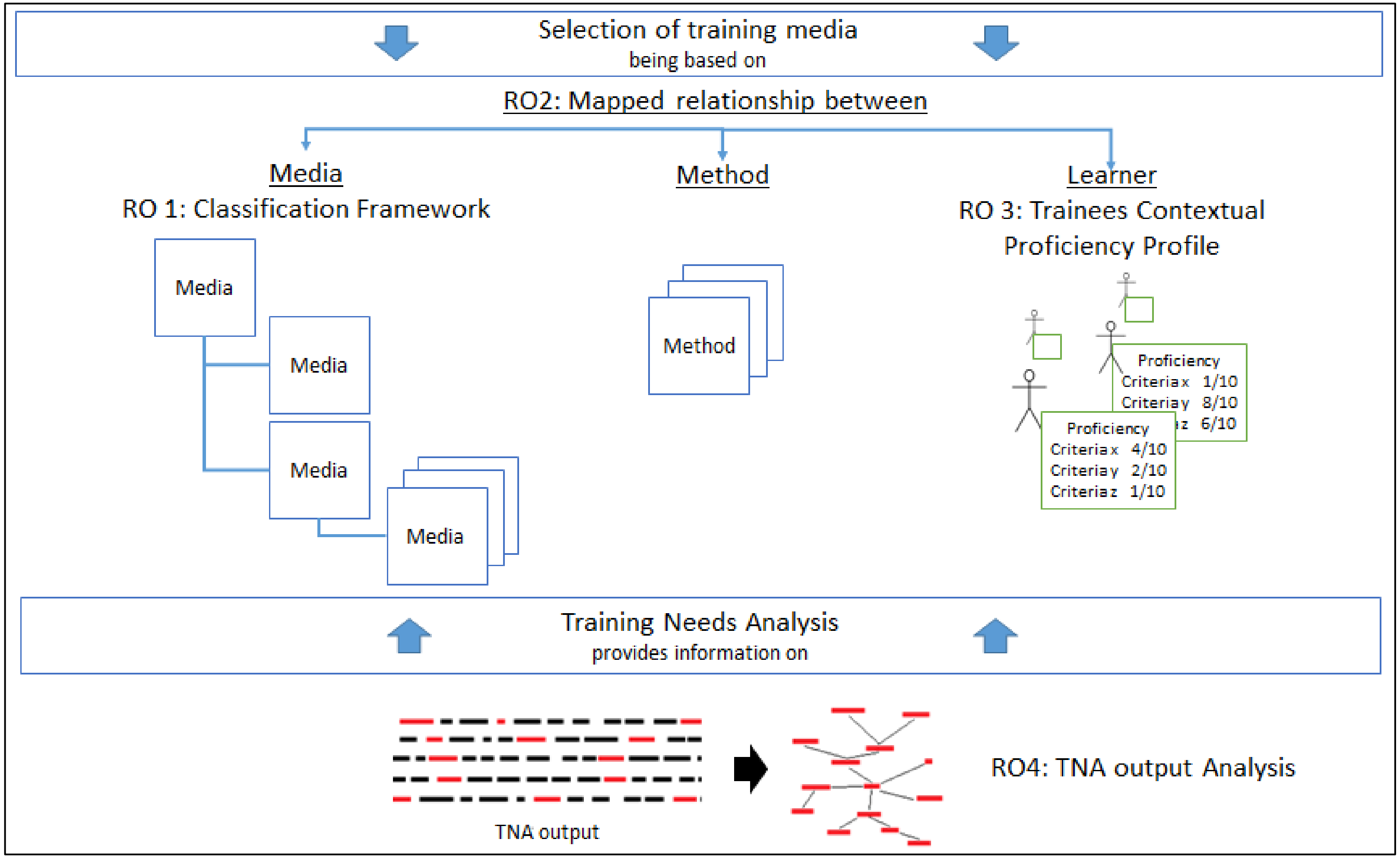

Figure 1.5 Diagram illustrating the problem space and how the research outputs fits within it. Illustrated by structure and classification of media offered by research output (RO) 1, the mapping between media, method and learner provided by research output 2, the learner proficiency profile delivered by research output 3and the analysis and visual representation of TNA outputs produced by research output 4 (as summarised in Table 1.2)

Chapter 2

Methodology

Adopting a particular approach to carry out your research will impact greatly the way in which the research is conducted as well as how the findings are treated. The research approach defines the design of the research, which encapsulates the philosophical assumptions that the researcher takes, the strategy of enquiry and the specific methods that are employed to conduct the research (Creswell, 2009).

In this chapter the research approach and the objectives set to support the research efforts are going to be introduced as well as the methods selected to carry out the research. The chapter is split into four main sections. A brief summary of the main research philosophies and methodologies considered is presented in Section 2.1. Section 2.2 will discuss the selected research approach and presents the research objectives while the specific research methods used within each step of the approach are going to be discussed in section 2.3. At the end, section 2.4 will present a summary of this chapter.

2.1 Research Philosophies and Methodologies

Philosophical perspectives reflect a set of beliefs and approaches that a researcher may take. They influence the decisions on how a study should be conducted, what counts as valid knowledge, what is the way to obtaining that knowledge, how the obtained data should be analysed and furthermore, what is the position of the researcher in the research process (Easterby-Smith et al., 1991).

Historically, there are two main types of research philosophies that a researcher may adopt; the positivist or the phenomenological (constructivist) approach. These are summarised in Table 2.1.

	Positivist paradigm	Phenomenological paradigm
Beliefs	The world is external and objective	The world is socially constructed and subjective
	The observer is independent	Observer is part of what is observed
	Science is value free	Science is driven by human interests
Focus	Focus on facts	Focus on meaning
	Look for causality and fundamental laws	Try to understand what is happening
	Reducing the phenomenon to simplest elements	Look at the totality of each situation
	Formulate hypothesis and then test them	Develop ideas through instruction from data
Methods	Operationalizing concepts so that they can be measured	Using multiple methods to establish different views of phenomena
Data / population	Large samples	Small samples investigated in depth over time

Table 2.1 Research Philosophies (Easterby-Smith et al., 1991)

Considering the positivist paradigm

The precursor study, conducted by Whittle and Valiusaityte (2010), took a positivist approach. The problem was formulated as a multi-objective optimisation task with the objective to provide a ‘near’ optimum solution by balancing effectiveness, cost and safety of training. The phenomenon under investigation was reduced to a set of variables such as, number of live, virtual and constructive entities, pilot experience level, number of air, land and sea entities and their offensive capabilities included in the training exercise scenario. However, when capturing the values of the pilot experience level from the perspective of skills improvement given various pilot training roles, several issues were encountered such as, the inability to set objective values. This issue, according to the researchers, was due to the fact that there are too many factors that influence the choice of specific values that cannot be easily captured.

Following their study, Whittle and Valiusaityte (2010) concluded that the optimal training regime is greatly context-dependent and all properties are extremely coupled and that more research is needed and perhaps other avenues should be explored to solve the media selection problem. In conclusion, although the study provides valid and valuable findings, a decision-making support solution could not be delivered by following this approach (Whittle and Valiusaityte, 2010). Furthermore, the authors themselves advocate for other approaches to be explore to better understand such a complex problem.

Considering the constructivist paradigm

The other main philosophical paradigm has been considered as well. The constructivist paradigm gives the possibility of analysis of a phenomenon in more depth (Easterby-Smith et al., 1991) and perhaps could offer insight into the issues found by Whittle and Valiusaityte in their study or help address some of them.

The phenomenological paradigm favours a focus of research on the totality of the situation rather than reducing the phenomenon to simple elements and trying to understand what is happening rather that looking for causality between the elements of a phenomenon (Table 1.1). Although by adopting a constructivist approach the researcher has the opportunity of investigating in depth a phenomenon, which is needed in this case, it does not satisfy completely the aim of the research project, which is the development of solutions.

Considering the Mixed Methods Approach

In the last few decades however, a third research approach or paradigm has emerged, The Mixed Method Approach, which is also known in the literature as the pragmatism paradigm (Johnson et al., 2007; Denscombe, 2008). The philosophical concept of pragmatism is based on the idea that there might cases where neither quantitative nor qualitative research methods will provide sufficient findings. Furthermore, the pragmatism philosophy is built on the belief that not only is it allowed to combine the two methodologies but that in some cases it is also desirable (Denscombe, 2008).

A mixed method approach was considered to be more appropriate for the research than the positivist or constructivist approach. That is because the other two philosophical approaches do not satisfy, on their own, the requirements of this research project.

Although there is evidence in the literature that the mixed methods approach was used before the ‘90s in research, only from that time onwards the approach emerged as, having a recognised name and a distinct identity (Johnson et al., 2007). Reviews (Rocco, et al., 2003; Descombe, 2008) of studies that used mixed methods approach reveal a variety of typologies and ways in which researchers have used and combined the quantitative and qualitative methods. For example, some researchers have used mixed methods to improve the accuracy of their data, some to produce a more complete picture by combining complementary types of data and sources, some used mixed methods to avoid biases intrinsic to single method approaches as a way to compensate for the specific weaknesses associated with the use of a particular method and others have used mixed methods to develop the analysis and build upon initial findings by contrasting quantitative and qualitative types of data and methods. (Denscombe, 2008)

Based on the ways in which the data could be mixed, the mixed methods methodology has evolved and contains a set of procedures that researchers have at their disposal when conducting research. Creswell (2003, 2009) proposed six strategies that a researcher may take in conducting a Mixed Methods research study. These are based on the timing of collection, analysis, weighting of the methods and mixing of the two types of data. The Mixed Methods Strategies are presented in Table 2.2.

Strategy	Description
Sequential Explanatory Strategy	Characterised by the collection and analysis of quantitative data followed by the collection and analysis of qualitative data. In this instance the former analysis (qualitative) is based on the findings of the first (quantitative). It is usually used when unexpected results emerge from a quantitative study and the qualitative data may help in explaining the odd results.
Sequential Exploratory Strategy	Characterised by the collection and analysis of qualitative data followed by the collection and analysis of quantitative data. This approach is better suited for explaining and interpreting relationships, to primarily explore a phenomenon and when a researcher needs to develop a tool or instrument. In this case, a three plan approach is employed: 1. Gather qualitative data and analysed it 2. Use the analysis to develop an instrument 3. Administer the instrument
Sequential transformative strategy	Gives the researcher the possibility of using either method in the first phase of the research and the weight can be given to either one or to be distributed equally.
Concurrent Triangulating Strategy	Allows the researcher to collect both qualitative and quantitative data at the same time and then compare the two databases to determine if there is a convergence, difference or other relationship between the data. Also, some of the researchers use this method to cross-validate the results of a study compensating therefore the weightiness of a method with the strength of the other.
Concurrent Embedded Strategy	Qualitative and quantitative data can be collected simultaneously but one of the method is going to be the primary method to guide the research and the data obtain by applying the other method is going to have a supporting role in the procedure, therefore having less priority than the primary method.
Concurrent Transformative Strategy	Allows the researcher to use a theoretical perspective as well as a concurrent collection of both quantitative and qualitative data.

Table 2.2 Mixed Methods Strategies (Creswell, 2009)

Considering the Systems Engineering approach

Given the purpose of the current research, that of developing a solution to a problem, the Systems Engineering (SE) approach was considered as well as a possible option. The SE approach, though used in research, is not included in the mainstream research methodologies and it is seen as something distinct from the constructivist and positivist approach.

The SE approach is

> *"an interdisciplinary approach and means to enable the realisation of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem: operations, cost and schedule, performance, training and support, test, manufacturing, and disposal."*
>
> (INCOSE, 2011).

The SE approach is instantiated by a SE process, which is an iterative process used in developing a solution-system to address an identified problem; i.e. *"an iterative process of top-down synthesis, development, and operation of real-world system that satisfies, in a near optimal manner, the full range of requirements for the system"* (INCOSE, 2011). Though there are several versions of this process in the literature such as, the V model and the Waterfall model, they are all based on the same SE approach.

As the Mixed Methodology, the SE approach has emerged from pragmatism, but while the mixed methodology implies use of a combination of methods appertaining to the constructivist (e.g. observation) and positivist (e.g. statistical analysis) research domains, the SE domain developed its own methods that cannot necessarily be labelled as appertaining to one of the two mainstream methodologies (e.g. Needs Means Analysis).

As the present research developed, it became obvious that the SE approach is not satisfactory on its own either, i.e. a complete solution-system that addresses the problem given by the customer could not be realised. The reason being that, the knowledge required to facilitate the development, or creation, of a complete solution-system (from a SE perspective) is currently unfeasible and various other questions have to be answered first in order to produce the required knowledge.

2.2 Selected Approach and Research Objectives

As such, from the six defined research strategies (Table 2.2) proposed by Creswell (2009) the Sequential Exploratory Strategy was considered to be the best fitting for achieving the aim of the current research project. This is because it provides a way for the research to focus on exploring a phenomenon in depth, which is required given the limited understanding there is about the problem space, then to using that information to develop a new instrument, which in this case is about developing support solutions.

Furthermore, as the three-step process that the Sequential Exploratory Strategy (SES) proposes (Table 2.2) is fundamentally similar to the Systems Engineering (SE) process, it was decided that a combination of the two will satisfy best the project requirements while addressing the associated research challenges. Like the SE process, the SES contains a series of steps that start with gathering information to understand the problem, followed by developing the instrument or tool (the solution) and then testing it (evaluate). The similarities between the two approaches are perhaps due because of the pragmatic philosophical perspective from which they have both been borne. These similarities between the two approaches are presented in Figure 2.1.

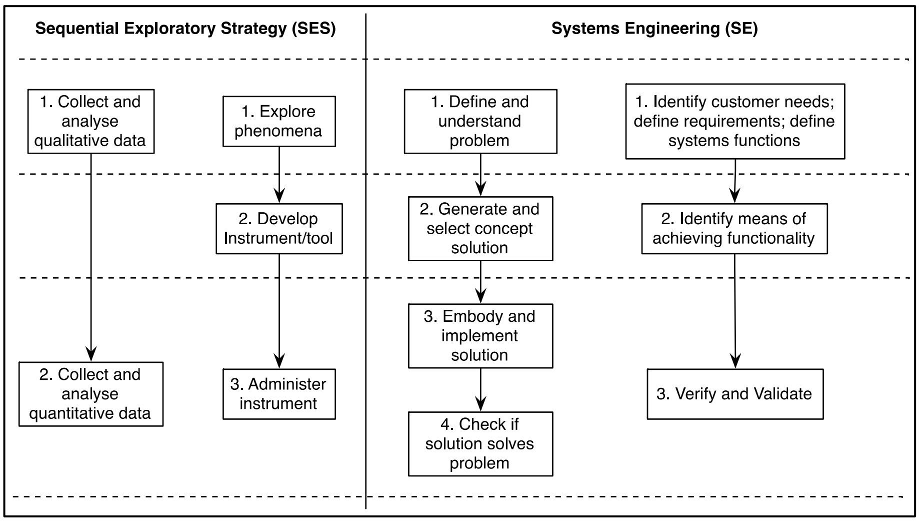

Figure 2.1 The Sequential Exploratory Strategy and the Systems Engineering process

Though fundamentally similar, the two strategies do differ, especially when it comes to the types of methods[7] that a researcher can employ at different stages in the two processes. While both do not necessarily impose use of specific methods they do imply use of specific types of methods. For example, SES implies use of quantitative and qualitative methods though does not specify what those should be, and SE implies use of testing or evaluation methods but does not specify what specific methods one should employ as this depends on type of system developed and stage of development.

To support the research effort, a series of research objectives were set. These are presented in Table 2.3.

Research Approach	Research Objectives
1. Explore and understand the problem	1. Investigate the problem area through literature review.
	2. Investigate the problem area from industry point of view.
	3. Document the issues and gaps extant in practice (industry) and theory (literature).
	4. Gather, analyse and validate stakeholders' requirements.
2. Develop solutions	5. Develop decision support solutions.
3. Evaluate	6. Evaluate the proposed solution.

Table 2.3 Selected approach and research objectives

[7]Method here should be understood as a way of doing something or as a tool that can be used to achieve something; i.e. it provides information on *how* something is to be done. This is different to strategy or process which should be understood in this context as a set of steps to be followed; i.e. it provides information on *what* needs to be done.

2.3 Selected Methods

The way in which specific methods were employed at each step of the research is summarised in Table 2.4.

Research Approach	Research methods
1. Explore and understand the problem area	Case study (interviews, observation and document review)
	Requirements elicitation: Interviews
	Requirements analysis: grounded theory analysis
2. Develop solutions	Critical reflection and deductive reasoning
	Concept analysis
3. Evaluate	Data flow verification
	Face-to-face validation through non-interactive simulation
	System verification through checking the outputs compliance with high-level requirements and validation through high-level validation of requirements (customer approval)

Table 2.4 Employed research methods

2.3.1 The 'Industry Perspective' study

Strategy of enquiry

In the initial phase of research, exploration of the problem area, two investigative studies have been conducted (Table 2.4). In the first, 'Industry perspective' (presented in subsection 1.2.3 of Introduction chapter) information on the issues of selecting media for training was sought to be identified, while in the second, 'Needs and Requirements' (presented in subsection 1.2.3 of Introduction chapter) specific requirements for development of support solutions were gathered.

To gather information on the perspective of industry, the case study[8] method was considered to be the most appropriate method of enquiry. Case study, as a method, is a specific qualitative strategy in which a process, activity, event or person are explored in depth by the researcher (Creswell, 2009) by collecting different information about the subject under investigation from multiple sources, using a variety of data collection procedures over a certain period of time (Stake, 1995).

This method was particularly beneficial in this case where various information about training media selection and training programmes construction where found by interrogating different type of sources (e.g. documents, people) and through different procedures (e.g. observation, focus group). Furthermore, this strategy of enquiry was followed because it allows the investigation of a phenomenon (construction of training programmes) in its extant context, and because this method is particularly recommended when the exact boundaries between the phenomenon under investigation and its context are not clearly evident (Yin, 2002); i.e. construction of the training programmes are interdependent and closely related to the resource system, doctrine and organisational culture. There were also practical reasons that had to do with availability of experts and restrictive rules regarding collection and management of information that influenced the decision to follow a case study strategy. Interviews or extended investigation would have required special permission and more time allocated to gathering and processing of data.

The choice of adopting a case study strategy clearly influenced the type of questions asked and further the procedures of analysing the data. In qualitative case studies, the research questions must address the description of the ‘case’ and the themes that emerge from studying it (Creswell, 2009) and it is recommended that the questions should be formulated in such a way that they begin with the words ‘what’ or ‘how’; focus on a single phenomenon; use exploratory verbs; use open-ended questions non related to the theory or literature and specify the participants and research site (Creswell, 2009).

[8] The term “case study” can be used either to refer to a unit of analysis (e.g. a case study of a specific event) or to a research method (www.qual.auckland.ac.nz). The term is utilized here as describing a research method.

Following Creswell's recommendations, the questions addressed through this case study where formulated in the following way:

- How do decision-makers make their decisions?
- How do decision-makers choose the components (e.g. training media/equipment) of the training programmes?
- What processes do they use to select the media for training?
- What factors impact the selection of media for training?

Collection of data

Relevant information from SMEs were collected from September 2011 through October 2012. This includes:

- Four two hours' focus-groups interviews with Flight and Synthetic Trainers SMEs at Abbey Wood (de&s[9]); Cockpit lead military training SME, Training development SMEs and Aircrew Training Managers at BAE (BAE Systems - Warton); Air-Ground SME and Wg Cdr (retired) at Waddington (ABTC[10]); Flight Simulation and Synthetic Trainers SME's and Flying Training Development SME's at Abbey Wood (de&s) adding up to nineteen interviewed SME's
- One telephone interview with Virtual Training System architect from CATT[11] (Lockheed Martin)
- One Apache Helicopter attack training exercise observation at School of Army Aviation (Middle Wallop)

Due to the explorative purpose of this phase of the research, the groups and the one-to-one interview were run with no strict, predefined questions. This is because unstructured interviews give the possibility to the researcher to explore various aspects of the subject under investigation (Stanton et al., 2005), which is the case in this exploratory phase of research. However, the topics that there were introduced for

[9] Defence Equipment and Support
[10] Air Battlespace Training Centre
[11] Combined Arms Tactical Training

discussion where not randomly selected but they reflected the previously identified research topics (introduced in subsection 1.1.4 Project aim).

The information was collected by taking hand-written notes. Because of the security issues at the sites where these interviews took place and the subject under investigation, no sound or video recording devices were used.

In addition, industry documents related to training programmes constructions have been analysed. These are the researchers' notes on *"The Training Optimisation Study"* (Whittle and Valiusaityte, 2010).

Data analysis

The gathered information was collectively analysed by following Creswell's (2009) six steps data analysis process. These steps are:

1) Organise and prepare the data for analysis;
2) Read through all the data;
3) Code the data and
4) Identify the common themes;
5) Decide how the themes will be represented and the final step,
6) Make an interpretation of the data.

In the process of data analysis, first, the collected data was reviewed (as a whole not per individual) and common themes identified. Then, the themes were used as table headings and chunks of data were placed under each theme (data coding). Following this step, the themes and data were reviewed and connections made between the themes and chunks of data.

Reliability, validity and generalisability of the case study

Validation and reliability of qualitative research findings relies mainly on the process of following and documenting as accurately as possible the research steps followed (Yin, 2003; Creswell, 2009), hence the sections to describe the method, data collection, data analysis and citations used to support the results and discussions section. In addition, specific validity strategies have been actively incorporated in the presented research, such as triangulation (different data sources of information have been investigated that showed similar findings) and members checking by reporting and validating the results of the study with industry experts.

Qualitative studies however, have limited generalization and the results are relevant to the specific context in which the study took place (Creswell, 2009). Therefore, the results of the present study should be read with caution and readers should note that the findings are particular to the discussed case and section of industry rather than applicable to the whole industry. The results from this case study were used to identify relevant issues within the problem area and define the research questions. Because the results of these types of studies are difficult to be applied from a specific context to a more generalized application in other domains/context, the research was targeted towards the UK military pilot training domain.

2.3.2 The 'Needs and Requirements' study

Requirements elicitation is a specific Systems Engineering approach that encompass three main phases: requirements gathering, requirements analysis and requirements validation. In this phase of research, qualitative specific methods are also employed, such as interviews and members checking for requirements gathering and validation. The interview method is an accepted Systems Engineering technique used to identify requirement (IEEE, 1998).

Requirements collection

Sixteen SMEs were interviewed at BAE Systems site during a two weeks placement in November 2012. The interviewed SMEs have expertise in aircrew training, modelling and simulation and human factors. The interviews duration was around one hour and they were a mix of face-to-face and telephone conversations run with single or multiple individuals, depending on participant's availability. Due to site security considerations the data was recorded using only hand-written notes.

A series of pre-determined questions focused on particular topics were prepared in advance and used throughout the interviews. These can be found in Appendix 5. The questions were focused on topics such as desired properties, systems interfaces, system performance and functions. The SMEs that participated in this study were informed verbally and in writing about the scope, use and management of information collected from them (see Appendix 6).

Requirements analysis

The information collected from SMEs during the requirements elicitation phase was transcribed in electronic format before analysis began. The IEEE Std. 1233 (1998) and Burge's (2006) HRM Tool Box were used as guidance to organise the information and categorise the requirements. Initially, a list of 193 formed Requirements was identified that was then revisited, reorganised and categorised as operational, functional and non-functional (system, performance, implementation).

However, developing a complete and comprehensive set of requirements involves many parallel and iterative developments and how this is out of scope of the current research, it was decided that a data analysis qualitative approach, such as grounded theory analysis, was more efficient as a method of analysing requirements.

By applying ground theory, four main categories of needs (or desired capabilities) where identified. These where further used to support the development of solutions to achieve the desired capabilities.

Requirements validation

The requirements were presented for validation to the SMEs at BAE Systems, which is seen in this context as the customer. An outline of how the solutions that were developed comply with the requirements is presented in the Evaluation Chapter (Chapter 5).

2.3.3 Development of Solutions

During this phase of research, various techniques were employed to analyse and combine existing knowledge to derive new, innovative solutions to answer the research questions. Considerable effort was put into analysing the relationship between some of the main concepts underlying the decision-making problem of media selection, which are: the media, the instructional methods and the cognitive process of learning. This part of research was conducted with the purpose of answering 2nd

Research Question: What is the role of media and method in training? Critical reflection of existing theory and research as well as deductive reasoning (see Table 2.4) were employed to create conceptual models of these relationships. As a result, a series of four models were produced, in which different aspects of the relationship between media, method and learning are mapped out. These are:

- A cognitive perspective of the interaction between media and the learner (Fig. 4.11 in Chapter 4)
- A model mapping the interactions between Training Media, the Learner and the Instructional Methodology (Fig. 4.13 in Chapter 4)
- A new proposed strategy towards Training Media Selection (Fig. 4.14 in Chapter 4)
- A unified selection framework of Instructional Process (Fig 4.15 in Chapter 4)

To answer the first research question, how can training media be differentiated?, the concept analysis technique (Table 2.4) was used. The results of the analysis supported the creation of a multidimensional Classification Framework of Training Media (section 4.1 in Chapter 4). The concept analysis implies the use of words as data units in order to arrive at a coherent definition (Streubert and Carpenter, 1999) and helps to clarify meaning (Burns and Grove, 1993). The concepts analysed were related to elements consistently found in media definitions and classifications across various disciplines such as, training construction and technology development.

Research effort was also allocated to providing solutions for the expressed industry needs of bridging the gap between the analytic stage and the technical/design stage when it comes to training requirements transfer (4th research question – How can TNA information be managed?), and the need to support tailoring the training programmes to individual pilot (3rd research question – How can the differences between trainees' previous experiences be identified?).

For the requirements transfer issues, a novel method of managing and visualising requirements was proposed to support not only the transfer of requirements but also to enhance storage, manipulation and visualisation of requirements; the ToA tool. For the development of ToA, various methods and techniques were employed (which are discussed in more detail in Chapter 4, section 4.4). Existing knowledge related to requirements expression, English language structure and network-visualisation tools were explored and combined to produce the ToA tool.

To address the need to provide a solution to support construction of training programmes tailored on individual pilot needs, the literature concerning competence and competency assessment was explored and a method to analyse the pilots' contextual proficiency profiles, the TCPP, was developed.

2.3.4 Evaluation studies

Evaluation, in Systems Engineering (SE) terms, is a process applied to verify and validate a system. As the research outputs are not integrated into a whole solution system, because of the type of developments (e.g. models that map various types of interactions) not all research outputs could go through the same evaluation process.

All developed models (the Media-Learner cognitive interaction model, the Media, method, and learner interaction model, and the novel strategy of Media Selection), frameworks (Training Media Classification Framework, and the unified Selection Framework of Instructional Process) and concept-tools (the TCPP and ToA) have been presented to the customer for feedback and comments (known as the pier-review method or face-to-face validation in SE). However, the TCPP and ToA have gone through a more comprehensive evaluation process that the rest of the developed models and frameworks.

TCPP and ToA

Two data sets were used to evaluate the TCPP and ToA concept solutions; one was extracted from the literature, more precisely from the Pike and Huddlestone (2011) research study, while the other data set was provided by the customer (BAE Systems). Furthermore, to demonstrate how they work and to facilitate feedback from the customer, a concept demonstrator was build and the tools presented to the customer for evaluation. For ease of demonstration, the two tools were presented as two separate modules in one concept-demonstrator system.

The concept-demonstrator is a non-interactive computer simulation (a mock up) that mimics what the tools would do if they would be in operation. The demo was built and run on PowerPoint using the OmniGrafflle application to create the tools' interfaces.

The TCPP and ToA were developed with the aim of integrating them with a decision support computer-based system. However, as being at the stage of concept a couple of artifacts were used to facilitate the evaluation process and build the demonstrator (e.g. Cytoscape). The artifacts used will be presented and further explained in the Evaluation Chapter (Ch 5).

As mentioned in the previous section, two data sets were used to evaluate the TCPP and ToA. Throughout the rest of the thesis the data set from Pike and Huddlestone (2011) research study will be referred as Data Set 1 and the data set provided by BAE Systems will be referred as Data Set 2. These data sets were used in two separate case studies that will be referred as Case Study 1 for the one were Data Set 1 was used and Case Study 2 for the Data Set 2.

2.4 Chapter summary

This chapter started with a discussion of the mainstream research philosophies (positivist and phenomenological) and their suitability to be applied to the current research project. This was linked with the pragmatic philosophy that underpins the Systems Engineering (SE) approach a connection was made between the SE approach and the Sequential Exploratory Strategy (SES), which is a Mixed Methodology Approach derived from same pragmatic philosophy as SE approach. The SES allows use of qualitative and quantitative methods to explore a phenomenon, interpret relationships and develop tools or instruments. As the SES, the SE approach allows use of various methods to explore and understand the problem space and then to derive solutions for system design and build. In the second part of this chapter, the specific methods employed at each of the steps in the research are summarised (Table 2.4) and discussed (section 2.3).

Chapter 3

LITERATURE REVIEW

An essential part in any research is the investigation of the literature on the subject matter. This research project aim is to develop computer-based solutions to support trainers in construction of UK pilot training programmes. Initial investigation into the problem area (the preliminary literature review and customer requirements) revealed that there are many issues, or gaps, which need to be solved (summarised in section 1.4 Research Questions and Outcomes). The time frame and resources to complete a PhD project is not sufficient to address all of them and the decision was made to focus on just some of the issues where it was considered that value can be added to current knowledge. As such, four main research questions were set for this research to focus on:

1) How can training media be differentiated?
2) What is the role of media and method in raining?
3) How can the differences between trainees' competences be identified?
4) How can TNA information be managed?

To help answering the research questions the literature appertain to the following areas of knowledge has been investigated:

- Classification of media
- The role of media and method in training/learning
- Assessment of competences
- Development of Decision Support Systems and management of information

Details about the method followed to investigate the literature are presented in section 3.1 Strategy. The main body of this chapter, section 3.2 Reviewed Literature, presents literature relevant to the gaps identified and the chapter will end with a summary of conclusions presented in section 1.4 Conclusions.

3.1 Strategy

To gain insight into the problem area relevant literature was identified using the keyword search technique querying various databases, such as libraries and other online repositories, i.e. Google Scholar, Science Direct and the repository of Loughborough University Library. Using this method, a variety of useful articles, journals and handbooks have been identified.

Following the initial stage of the literature search, additional techniques have been employed to advance the knowledge and probe deeper into the phenomena under investigation, such as backward and forward search (Webster and Watson, 2002; Levy and Ellis, 2006). These techniques were centred on author and references. The backwards search approach was employed to investigate from where concepts and theories found in various sources (e.g. journal articles) originate, while the forward search was used to extend the knowledge by investigating follow-up studies and developments related to the concepts and theories under investigation.

This approach has been selected based on the recommendations and instructions provided by the "Information Science Journal" (i.e. Levy and Ellis (2006) paper "A Systems Approach to conduct an Effective Literature Review in Support of Information Systems Research") for doctoral students researching Information Systems to conduct effective literature review. This approach was selected because it offers a comprehensive guide on each step of the process (a Systems Engineering approach) and a sound rational. Furthermore, the subject of this thesis is mainly focused on development of systems to support the management of different types of information (e.g. information on trainees' competences; management of TNA information).

Although the backwards and forwards techniques do offer valuable additional sources as the research progresses, it does give a feeling that the literature review could be a never-ending process (Levy and Ellis, 2006). However, there is a common rule of thumb that researchers can apply during the literature review process, which was applied in this case as well. That is that the literature search is near completion when it is found that new literature only introduces familiar knowledge (Leedy and Ormrod, 2005; Levy and Ellis, 2006).

During the literature review process it was found that some of the investigated themes do not belong to the same field of research or discipline. Some themes or concepts appertain to sub-domains or crossed boundaries between disciplines. For example, 'training programmes' is related to training domain but also to systems engineering domain, research on media is done in the modelling and simulation domain and also the training domain, resource-efficiency is researched in logistics (or operational research) as well as in systems engineering. Therefore, given the expansive problem area, as the research progressed decisions were taken to concentrate the research towards specific areas where it was considered to be a more pressing need for research and a more valuable contribution to the body of knowledge could be made.

The interdisciplinary characteristic is recognised as being one of the challenges inherent in this type of research (Webster and Watson, 2002; Levy and Ellis, 2006) and it is recommended that for an effective literature review a concept-centric approach would be more suitable rather than an author-centric one (Webster and Watson, 2002). This ensures that valuable work conducted in other domains or sub disciplines will not be missed (Levy and Ellis, 2006) and a more complete picture of the phenomenon under investigation can be built. Furthermore, Barnes (2005) recommends that during the literature review the researchers should make use of the sources that substantiate the presence of the problem under investigation. These recommendations have been fully endorsed in the present research and represent the core strategy that guided the literature review process.

3.2 Investigated Literature

3.2.1 Classification of training media

During the first part of this research, investigation of the problem area, presented in Chapter 1, it was identified that there is an issue of lack of clear separation between different types of media (hence 1st research question: How can training media be differentiated?). This can hinder comparative assessment of training media.

In the past decades, due to technological developments in the simulation domain, there is an increase in the use of simulation in air-force training alongside live training. The advantages of using simulations are well documented and recognised (NSTA, 2010).

For example, it helps in the development and rehearsal of pilots' capabilities, promotes continuous training (Cohn et. al, 2009) in a safe environment and improves readiness for front line operations (Shufelt Jr., 2006) while reducing the training costs (Kirby et. al, 2011).

The use of embedded systems on live aircraft to simulate weapons systems, use of head-mounted displays to simulate real-world or augmented reality add complexity when it comes to categorising training as being live or synthetic (Kirby et al., 2011). Furthermore, with technological developments, innovative mixes are enabled, which resulted in the introduction of new blended media technology systems (van der Pal et al., 2011).

Although generally accepted, the LVC breakdown has long been recognised as being problematic (Ausink et.al, 2011) because of the lack of clear boundaries between categories. For example, the degree of human participation within simulation as the degree of equipment realism is highly variable (DoD, 1998). Furthermore, the LVC classification suffers by excluding the category of simulated entities that operate real equipment (DoD, 1998).

The consequence of rapid technological developments, coupled with lack of research on definitions and classifications regarding training media technologies, is that it became increasingly difficult to clearly bound (classify and define) training media systems, i.e. blending's of various types of media are posing semantic concerns (van der Pal et al., 2011), which in turn hinder communication across domains and can inhibit development.

To be efficient, a classification framework needs to identify essential differences (Milgram and Kishino, 1994). As Kirby (2011) states: "the idea of pure live/synthetic balance is a fallacy"; therefore the focus has to be shifted from LVC descriptions to find novel ways of differentiation between training environments to accommodate the current needs. Attempting to distinguish between the classes only on the basis of media type might not be sufficient for every level of abstraction when dealing with training equipment. Media is a dimension and therefore, differentiating based on media type is necessary but not sufficient.

This research focused on the development of a more rigorous and unambiguous definition of media within training.

3.2.2 The role of media and method in training

Part of the customer requirements for developing a decision support solution was to develop an approach through which training media can be objectively assessed for its impact on training, i.e. in achieving the training objectives, as well as a method through which different media can be compared based on their efficiency and effectiveness.

One issue faced by decision-makers in constructing training programmes, which was identified through the review of existing tools for media selection (Section 1.3.2 in Chapter 1), is that there is no approach or tool to objectively inform the selection of media for training. All surveyed approaches, developed so far, rely on the subjective judgement of decision-makers to evaluate the effect of the training media on the training outcome. That is perhaps because there is a lack of research into quantifying the effects of employing all available training technologies on the learning process.

However, before starting to develop a solution to evaluate or support the evaluation of the impact of the various training media and combination of training media on the training outcome, there are other issues that first need to be addressed. Besides, how we differentiate between various types of media (which was covered in the previous section), it is important to understand how we differentiate between media and method, what is the relationship between media and method and what is their impact on the learning process? (hence 2nd research question: What is the role of media and method in training?)

Extant approaches and tools, which were presented in the Introduction chapter, treat media as having little to no influence on the learning process and that the media role is to support the delivery of the instructional methodology. Furthermore, the method of instruction is considered as being that element of training that influences the choice of media. Therefore, all these approaches and tools developed to support media selection for training have a similar approach: identify, select or develop the instructional methodology and then, select media that will support the chosen instructional methods.

Clark in 1994, following a survey of studies that looked at the effect of employing various media in learning, concludes that media is not a causal agent in learning and that media does not influence learning. Clark (1994) motivates his position by citing studies that show that there is no media that possesses unique attributes that are necessary for learning.

While there is compelling evidence that there is no single media that possess such unique attributes, this does not necessarily justify the conclusion that media does not have an effect on learning. Kozma (1994) in reply to Clark's conclusions brings forward Shuell's (1988) definition of learning where learning is seen as being an *"active, constructive, cognitive and social process by which the learner strategically manages available cognitive, physical, and social resources to create new knowledge interacting with information in the environment and integrating it with information already stored in the memory"* and concluded that knowledge and learning are neither property of the individual nor the environment but rather it is a property that emerges from the interaction between the learners' cognitive resources and their external environment (Kozma, 1994). The question is then if media, as part of the learner's environment is a passive or an active element in the learning process?

Kozma (1994) argues that, to understand the role of the media in learning, we have to research the mechanism through which media might interact and influence the cognitive process of learning and encourages researchers to further explore the possible relationship between media and learning to be able to understand it and ultimately to use it for its potential benefit to learning.

One way through which media interacts with the cognitive system is to 'deliver' as suggested by Clark (1994, and Sugrue and Clark, 2000). From this perspective, media interacts with and influences the cognitive process by delivering various stimuli (information) based on which the cognitive system (the learner) will react. However, following Shuell's definition, this delivery mechanism (media) will have properties contributing to the production of the new knowledge. This assumption, the idea of 'property' is similar to the concept of 'capability' discussed in Systems Engineering (SE) (INCOSE, 2014).

To explain, think of a weapon that has the capability to hit a target placed at X meters. The weapon on its own, cannot hit the target unless something or someone activates the trigger, if there is a projectile to hit the target and if the weapon is handled in a specific way. This example shows that a component, regardless of how inactive it might seem, possesses properties that once activated (used in a certain way) contribute (and therefore they are active) to obtaining a specific effect. This does not dismiss Clark's conclusion that media is a delivery mechanism but emphasises that media might have a more active role on the outcome (on learning) than Clark suggested.

The idea of media being active (participatory) in the learning process is further supported by Situational Learning and Distributed Cognition theories and research. For example Lave and Wenger (1991) argue that learning should not be viewed as simply the transmission of knowledge from one individual to another but as a process where knowledge is co-constructed.

Furthermore, an entire branch of research, the distributed cognition field, is based on the premise that knowledge and cognition are not confined but distributed in our environment through the placing of information and knowledge of objects, individuals or tools. For example, Hutchins (1995 a, in Vicente, 1999) through naturalistic observation of current practice in the domain of ship navigation found that knowledge and information processing are not confined to the brain but instead are distributed spatially across individuals and artefacts. This distributed placements form a set, or system, of representations where, information and knowledge are interchanged with the purpose of producing new knowledge. This perspective is also sustained by research (e.g. Norman, 1993; Perkins, 1993; Lehtinen et al., 1999) that advocates the distribution of the cognitive processes between human and machine. A very good description of this process is 'scaffolding' given by A. Clark (1997).

Now that media is seen as having (or having the potential of) a more active role in the production of learning, the question is how much of a role does it has?

Cobb (1997) suggests that media has the role of providing cognitive efficiency; a suggestion that is accepted even by Clark. Furthermore, Cobb (1997) draws attention to the fact that media has an effect on "how" something is learned rather than on "what" it is learned.

Broadening the concept of media efficiency with 'cognitive efficiency' as distinct from the economical type of efficiency, Cobb (1997) shows how media can possess features that will affect the learning process by influencing the cognitive effort required for the learning to happen and the interaction of the learner with a particular knowledge set. Cobb therefore puts forward the idea that the 'form' in which information is delivered (the media) is not just a passive element but an active one that influences how the information is going to be processed by the learner.

Having established so far that:

- Media has an active role in the production of learning
- The role of media in learning is to support the human cognitive effort

the question is now: How does media interact with the cognitive system to support the cognitive process?

Besides media, the training methods and the instructional process are key components in the construction of training programmes and any decision made regarding choice of media will be influenced by them. Instructional methods and instructional strategies are two terms that sometimes are used interchangeably and sometimes separately. When used separately, the understanding is that instructional strategies use particular methods, and a variety of methods can be found within a variety of instructional strategies.

In training, there is no single method used to deliver training (Salas and Cannon-Bowers, 2001) however, the instructional strategies are usually created around similar principles. The characteristics of the processes that form an instructional strategy can serve as a basis of filtering out media that do not possess attributes that support those characteristics. Therefore, an analysis was done to identify the basic characteristics of the processes involved in the design and development of the instructional strategy.

Atkinson and Shiffrin (1968) established the basic architecture of the memory system that explains how learning takes place. This is presented in Fig. 3.1.

Fig. 3.1 The multi-store model of memory (Eysench and Keane, 2005)

As pictured in Fig. 3.1, the cognitive learning process involves two basic complementary processes: attention and rehearsal. The environmental information (outside the cognitive system) is initially received through the sensory channels. However, not all information that bombards our sensory channels will end up being remembered or even noticed. In order for the information to pass on, into the short-term memory store, attention has to be directed to it; and for the information to be stored in the long-term memory a rehearsal process has to take place.

Based on the way the cognitive system processes and stores information, instructional designers have created various strategies to guide the training process. For example, Gagne (1977) devised a series of nine instructional events that are linked with a series of internal mental processes necessary for learning. These are presented in Table 3.1.

Instructional event	Internal mental process
1. Gain attention	Stimuli activates receptors
2. Inform learners of objectives	Create levels of expectation for learning
3. Stimulate recall of prior learning	Retrieval and activation of short-term memory
4. Present the content	Selective perception of content
5. Provide "learning guidance"	Semantic encoding for storage long-term memory
6. Elicit performance (practice)	Responds to questions to enhance encoding and verification
7. Provide feedback	Reinforcement and assessment of correct performance
8. Assess performance	Retrieval and reinforcement of content as final evaluation
9. Enhance retention and transfer	Retrieval and generalisation of learned skill to new situation

Table 3.1 Gagne's (1997) nine events of instruction

Sugrue and Clark (2000) identify six type of methods of instructions:

i. Elaborate the goal of the task and its demands
ii. Provide information related to the task
iii. Provide practice tasks and context
iv. Monitor trainee performance
v. Diagnose sources of errors in performance
vi. Adapt goal elaboration, information and practice tasks

Following, Salas and Cannon-Bowers (2001) identify four basic principles that instructional strategies are created:

i. Presentation of relevant information or concepts to be learned
ii. Demonstrate the knowledge, skills and attitudes (KSAs) to be learned
iii. Create opportunities for trainees to practise
iv. Provide feedback to trainees during and after practice

However, there is a lack of a unified model that trainers could follow in developing their strategy for instruction. A unified model could help to increase consistency of training programmes constructions and therefore more research should be focused on this area.

3.2.3 Assessing trainees' competences

During the problem space exploration phase of this research, presented in Chapter 1, there was also identified the need to support the construction of training programmes not only to be created based on operational requirements but also on pilots individual needs (hence 3rd research question: How can the differences between trainees' competences be identified?)

The environment in which training takes place is defined by the application for which training is required, whether it is a skill to be practised individually or within a team, and the type of skill (cognitive, perceptual, and motor) required to be trained. As such, before embarking in any activity related to the construction of training, an important analysis is that of the audience to be trained. Beside factors such as number and location, extant audience knowledge and skills is of importance, as this will help the decision makers to tailor the training for the specific needs of the audience. The results of such an analysis also serve as input to the realisation of the actual training environment.

TNA and gap analysis are examples of analyses where such factors are taken into consideration. Although, within these analyses, the idea is to highlight the differences between required competencies and present competencies, there have been criticisms that some factors are not taken into account, such as level of proficiency and context (De Coi et al., 2007, Bedeck et al., 2011).

In the area of assessment of competencies efforts have been made to provide frameworks and models for more comprehensive assessments (Symons et al., 2006; De Coi et al., 2007). One such promising framework is the one developed by De Coi and colleagues (2007) that introduces a model for representing a competence within a broader view.

The De Coi and colleagues model is based on a three-dimension view of competence where competence is composed of: competency, proficiency level and context. Competence (plural competences) is defined as the "effective performance within a domain/context at different levels of proficiency" (Cheetam and Chivers, 2005) and competency (plural: competencies) is understood as being a specific skill or knowledge.

However, the De Coi model is perhaps better regarded more as a framework on which to build with domain specific elements a domain specific model for assessment of competences. More specifically, the three dimensions that the model takes into account; the context, proficiency level and competency have to be populated with domain specific elements, proficiency scales and domain specific competencies.

MECs are the Mission Essential Competencies framework, developed by the U.S. Air Force Laboratory and Air Command Combat. It defines pilot/team competencies required for successful mission completion (Symons et al., 2006). MECs usually serve as input for specifying training objectives and to design scenarios for training. MEC is a hierarchical model where pilot competencies are further decomposed into

"Supporting Competencies" and "Knowledge and Skills" so that specific training objectives can be specified. For example, for Air-to-Air combat missions there are the following competencies: "adaptability", "communication", "identification" and their associated knowledge/skills: "communications standards", "controls intercept geometry".

Although MECs can be quite useful in judging training scenarios, an analysis based only on MEC's will be limited when trying to identify the gap in skills of a pilot, as MECs do not address the context dimension. One could refer to the "Experiences" associated with MECs, which were developed as events necessary to learn or practise a particular skill under operational-like conditions (Symons et al., 2006). However, they are more task oriented (e.g. of Experience: limited fuel remaining) and environmental orientated (e.g. of Experience: night employment, mountainous terrain). "Experiences" do not take into consideration other contextual factors, such as operated platform and/or type of media environment where the pilot previously acquired knowledge/skills (e.g. synthetic, live in training or live in mission).

In military flight training, any identified 'need' comes as a requirement from the real life/operational environment and it is identified based on the analysis of the operational context. Further, it is judged how that 'need', can be accomplished. This is broken further into 'training objectives'. These further can be broken into tasks that are judged to be necessary and required to be performed in order for the objective to be achieved. This process is known as the task analysis process. Task analysis is a method, which encompasses an array of specific techniques through which information is gathered and organised in a comprehensive and formalised way so that it can be used as input for design decisions (Kirwan and Ainsworth, 1992).

It is assumed that who or what needs to operate in that environment does not possess the knowledge, skill or attitude (KSA) to successfully operate. However, the future 'to-be' operator can possess certain skills, knowledge and attitudes that are similar or partially similar with those needed within the future operational environment. Therefore, the question of how to capture the gaps in KSA still remains.

3.2.4 Development of Decision Support Systems (DSS)

Given the type of support solutions required to be developed by this project (e.g. management of TNA information, and management of information pertinent to assessment of trainees' competencies – see also research question number 3 and 4 in section 1.4 Research Questions and Outputs) it was considered imperative to investigate the literature regarding decision support systems and management of information. This was, on one hand because of the need to understand what the current knowledge regarding general management of information is and on the other hand, to understand how and where any developed solutions might fit within the current types of Decision Support Systems (i.e. important for design and implementation of any solution-tool).

Decision Support Solutions

Decision support solutions in broad terms could be defined as a product (either that is a tool or an approach) developed to add something to the decision-making process, to provide support to the decision-maker to solve a decision-making problem and/or improve the decision-making process itself (Hubbard, 2009). Decision support solutions therefore can be anything from paper-based to computer-based tools designed to either guide the decision-makers in their activity (e.g. a process/approach to be followed by decision-maker) or to provide support for navigating the stages of the decision-making process (e.g. presenting options to the decision-maker). Out of the two types of decision support solutions, the computer-based ones are of particular interest in this research as they are useful when there is a need to process high volume of information; hence the progression of support solutions from paper-based to computer-based. These computer-based support solutions for decision-making are usually referred in literature as Decision Support Systems (DSS).

Decision Support Systems

Although historically DSSs have been developed and implemented since the mid '60s there is still no universally agreed definition of DSS (Hubbard, 2009). This disagreement could be explained by the fact that there is no theoretical base underlying the domain itself (Parker, 1999); the study of DSS is an applied discipline that uses knowledge and theories from other disciplines (Power, 2008) ranging from psychology to systems science (Eom, 2008). Another reason might be that perhaps the domain is too vast and too varied for a single theoretical explanation. As such, there are a multitude of DSSs with a variety of functionalities.

For example, after examining several literature surveys and citation studies regarding the application of DSSs, Power (2008) concluded that the major application of DSSs emphasises manipulation of quantitative models, accessing and analysing large databases and/or supporting group decision-making, i.e. supporting communication between the members of the group. In terms of the operations that DSSs could perform, Alter (1980) differentiates between several categories of DSSs ranging from mostly data-orientated to mostly model-orientated, and when looking at the functionality of DSSs, Sprague and Carlson (1982) define the DSS as a type of information system that relies on processing systems and interacts with the other parts of the overall information system to support the decision-makers in their activity.

DSS development, started when the data processing activities began to be automated and computerised. From then on, the demand for systems that analyse data has increased with the need of managing and analysing ever-increasing quantities of data (Parker, 1999). As such, a new generation of systems called Management Information Systems (MIS) were created. The purpose of these types of systems was to process the data by applying standard algorithms to produce summary of data and to condense information into a format that could be used by the decision-makers in their activity (Parker, 1999). However, distinguishing between MIS and DSS is a matter of debate. Gorry and Scott Morton (1971) argue that MIS primarily focus on structured decisions while DSS focus on ill structured decisions. Especially, MISs are useful for reducing costs, time and improving efficiency when there is a structured problem or task where there are standard operating procedures, decision rules and information flow that can be reliably defined; while DSSs are mostly used to increase the decision makers' capabilities where the problems are ill structured and the decision makers' judgement is essential (Parker, 1999).

Parker (1999) argues though that the distinction between MIS and DSS is primarily historic and that MISs are forerunner of DSSs and that nowadays MISs are incorporated within the DSSs. Furthermore, she suggests that a more useful distinction to be made between them could be to look at the level of support that they provide rather than at the structure of the problem for which they are designed. Through their function, it can be argued that MISs are systems that support the decision making process through provision of information while DSSs are designed to support the decision making process itself. This is not to say that a DSS does not provide information but that its role is much greater and that the information should be provided in such a way that the decision made with the support of DSS becomes easier and more effective (Parker, 1999).

MISs are not the only type of information systems that have been created as systems to support decision making. There are a multitude of such systems, as for example: Transaction Processing Systems (TPS), Executive Support Systems (ESS) and Knowledge Work Systems (KWS) that have been developed to support decisions made at various levels (from operational to strategic level) and to be used by different types of decision makers (from technical staff to senior management). The disagreements and debates surrounding definition of systems that support decision making are largely due to the type of support offered to the decision-maker to solve the problem (i.e. it is just to support or to improve the decision-making process?) and for what type of problem the system is designed (e.g. structured vs. ill structured).

Decision-making problem structure and DSS support

How well a problem is structured for which a decision support solution is required is important, as this will determine the type of support solution system designed. Keen and Scott Morton (1978) differentiate between three types of problems:

- Structured (where tasks could be carried out by inexperienced personnel and therefore could be easily automated),
- Semi-structured (where the size and/or complexity of the problem to solve is cognitively intense or beyond the decision-makers capability)
- Unstructured (when the problem to solve cannot be quantified or mathematically modelled)

Basically, when it comes to structure, the decision-making problems can be viewed as sitting on a continuum where at one end we have the structured problems, which are those problems where all the factors relevant for making the decision are well understood, the alternative options are clear and each can be evaluated and compared (Holsaplle, 2008); and at the other end we have problems where not all the factors pertinent to produce a decision are well understood, the alternative choices are vague or they are difficult to compare and contrast because the alternative options are either difficult to evaluate or they are unknown (Holsapple, 2008).

DSSs are proposed as being valuable solutions for dealing with ill structured decision-making problems (Keen and Scott Morton, 1978) as they could be designed to facilitate the exploration of knowledge (i.e. problem and solution space), provide methods for reaching decisions, store and analyse results of brainstorming, provide multiple perspectives and stimulate decision-makers creative capabilities (Holsapple, 2008). Additionally, DSSs could be designed to be employed in carrying out some of the tasks in a structured decision-making problem and those making the process more efficient and less prone to human error (Holsapple, 2008).

In terms of support that could be provided, the DSSs could be divided in three categories: to assist the decision-makers in their activity when dealing with semi-structured decision-making problems, to support rather than replace the decision-maker judgement and to improve the effectiveness[12] of the decision making rather than its efficiency[13] (Keen and Scott Morton, 1978). An important aspect to be noted here is that if the system were to perform all the steps of a decision making process then that will be a decision-making system not a decision support system (Holsapple, 2008).

Decision-making: the problem context

A decision, as the activity undertaken to solve a problem, does not sit in a vacuum. The context or the situation in which the decision-making activity takes place may also impact the structure of the decision-making problem. For example, there can be

[12] Effectiveness – Producing the intended or expected results
[13] Efficiency – Producing the intended result in the best (optimal) possible manner with the least waste of time and effort

cases when a structured problem becomes unstructured when the application of known rules (e.g. optimisation techniques) may not be possible (Parker, 2009). Furthermore, there can be cases where the decision-making problems cannot be pigeonholed as structured or unstructured in their entirety but only in respect to particular stages within the decision-making process. The decision-making process as a whole can be divided in three main consecutive and iterative phases: 1) obtain information, 2) gather alternative and 3) select choice. Keen and Scott Morton (1978) propose that a fully structured decision-making problem is one in which all the three phases are structured.

Examining Keen and Scott Morton's (1978) classification of decision-making problems based on structure, it could be concluded that, the degree of structure of a problem decreases with the increase in the complexity of the problem. Furthermore, Holsapple (2008) suggests that decision-making problems are considered ill structured when the knowledge required to produce the decision is unavailable, difficult to acquire, incomplete, not trusted or in a form the decision makers cannot use. From these statements (based on Keen and Scott Morton and Holsapple) it could be inferred then that the complexity of a decision-making problem is directly proportional to the amount of knowledge that there is about that problem. Or in other words, the less knowledge we have about the factors on which a decision relies, the greater the complexity of the problem and, therefore, the greater the lack of structure of the decision-making problem.

Complexity

Bennet and Bennet (2004) define complexity as the condition of a system, situation or organisation that has some degree of order but the amount of elements and relationships make it difficult to understand them in an analytic or logical way. Mainly, it is very hard to trace the cause and effect paths because they are too many and nonlinear in nature. Furthermore, these types of system exhibit various feedback loops and multiple interactions.

In the present research, the system is the decision-making problem in which the decision to be made relies on factors that are either not well understood or their effects are hard to quantify because they are not simple or there are no direct correlations between the variables (Whittle and Valiusaityte, 2010). Furthermore, the decision required to be made in such a context will most likely be unique (Bennet and Bennet, 2008) which makes it difficult for the decision-making problem to be strictly defined or bounded. In the present research, the decision is unique because it would be bounded by a set of circumstances (such as training requirements and available media options) valid at a certain moment in time.

Siemieniuch and Sinclair (2005) differentiate between two sources of complexity: inherent (also known as intrinsic) and induced. Inherent complexity arises largely from the interactions between the components of a system (due to the nature of the system itself) while induced complexity results from the way in which an organisation choses to address the problem (the process). If this rationale is applied to the decision-making problem addressed by this research, it could be said that intrinsic complexity is present due to the difficulty to map and/or quantify all possible interactions between the components, while induced complexity arises from the approach adopted to deal with the decision-making problem, i.e. the decision-making process itself.

One option to deal with the complexity might be to ignore those aspects that are not strictly related with the decision-maker's goals or objectives but, as Bennet and Bennet (2000) state that is more easily said than done. Simplifying (reducing or filtering the unnecessary information) takes skill and knowledge and inexperienced decision-makers may not necessarily possess them as these usually are assimilated through experience (Bennet and Bennet, 2000). In addition, there might be cases where ignoring certain aspects that may appear irrelevant may be counterproductive or lead to poor decisions. For example, in our case if we concentrated only on selection of media and ignored the selection of method, it may produce efficient but not effective decisions in constructing training programmes. By focusing only on the selection of media to support the delivery of training methods while the training methods remains the same could restrict the possible developments of training methods based on available technologies.

Due to its nature, intrinsic complexity cannot be completely removed or avoided however, it can be recognised and managed (Hubbard, 2004). To explore the possibilities of managing the complexity of the decision-making problem, the literature on information and knowledge management has been consulted as well.

Information and knowledge management

DSS and ‘knowledge’ are two terms that starting from the ’90s are increasingly used together in publications and this coincides with the emergence of the Knowledge Management (KM) field of research (Holsapple, 2008).

Burstein and Carlsson (2008) define Knowledge Management (KM) as being a continuous process of acquiring and deploying knowledge with the purpose of improving decision-making. The close relationship between KM and DSS is governed by the aim that they both have in common; that is to make the decisions taken based on information and/or knowledge more effective and efficient (Burstein and Carlsson, 2008). This could suggest that a primary role of the DSS is to manage knowledge rather than to produce it. However, this will depend also upon the view that one might have in respect of what is knowledge and information.

There is quite an extensive debate in the literature about what are knowledge, information and data and what is the relationship between these concepts (Holsapple, 2008). Some researchers see knowledge as encompassing a series of states (Van Lohuizen, 1986) where knowledge progresses from lower states to higher states while others view knowledge as a state in its own right where data are turned into information and information is turned into knowledge (Davenport, 1998). Both views however follow the same principle; that the concepts of data, information and knowledge are not interchangeable (Davenport and Prusak, 1998). The differences are mostly in the way these progression states are named (Holsapple, 2008).

The knowledge state perspective asserts that knowledge progresses from lower states such as data to a higher state such as information, insight and others in an orderly fashion through, or because of, a series of processes or operations such as selection, analysis, evaluation, etc. These processes do correspond roughly with Simon’s (1976) phases of decision-making: intelligence, design and choice.

Holsapple (2008) makes the observation that regardless of the way the states are established or named, what comes through is that the states highlight the different levels of usability of knowledge, where knowledge has limited usability when in lower state (e.g. data) and it becomes higher, clearer and immediate when in higher states.

This observation can be also applied to Davenport's view of knowledge as a state preceded by data and information. In Figure 3.2 is presented an edited version of Holsapple (2008) view of knowledge as a progression of states to which the concept of usability and Davenport view of knowledge have been added.

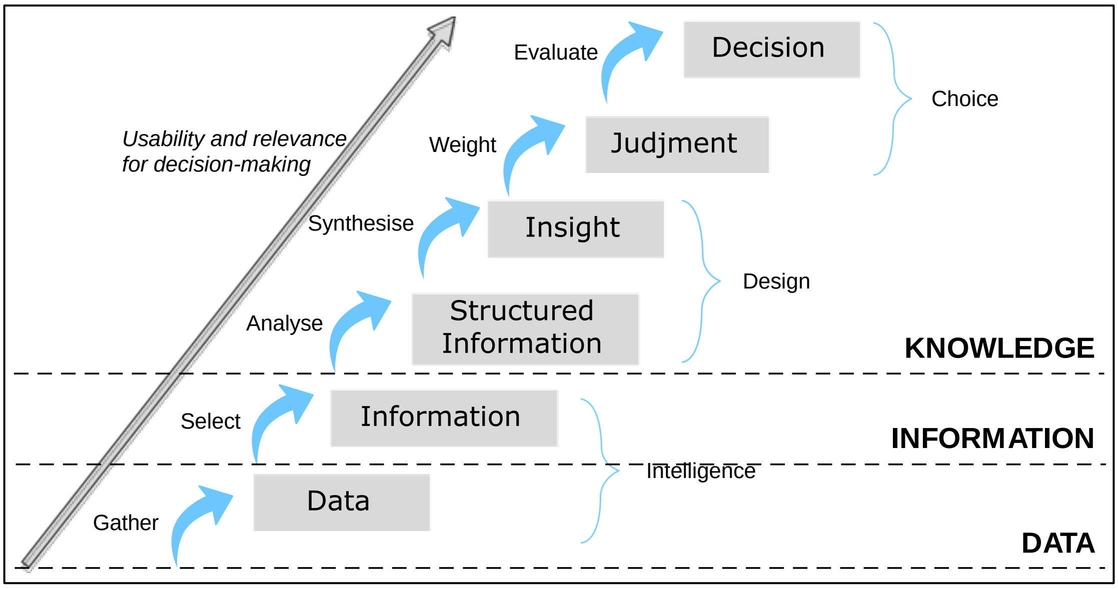

Figure 3.2 Knowledge progression states (Combining Davenport (1998) and Holsapple, (2008) views, and the concept of knowledge usability)

The usability dimension of knowledge is quite an interesting concept. For example, the systems perspective advocated by Newell (1982) does not impose such a strict threshold of knowledge when it comes to its use. In the systems perspective knowledge is viewed as being *"that which is embodied in usable representations"* (in Holsapple, 2008). Furthermore, Newell (1982) asserts that knowledge is not something that is easily seen but *"only imagined as the result of interpretative processes operating on symbolic expressions"*. It could be said then that the 'representation' of something, which can be anything from an object to a procedure, possesses knowledge or has that capability of knowledge, dependent on its 'usability' level.

One element is common to the system view and the knowledge progression view; that is that knowledge happens as a result of some processing of something (e.g. of a symbol). Now, a question might be how much that 'representation' or more precisely, how much the knowledge embedded in that 'representation' is of use and if it is of use in the same way for all users[14].

For example, if we take the following division between data information and knowledge as is given by Holsapple (2008):

- Data – are isolated observations or assertions (e.g. *"240", "John Doe"*)
- Information – results from relating, structuring and/or qualifying data in meaningful ways (e.g. *"240 is the level of cholesterol of John Doe"*)
- Knowledge – results from assembling the collection of information that is relevant to or applied to a task at hand (e.g. *"John Doe's level of cholesterol is now too high"*)

And apply the system perspective presented previously, two conclusions could be drawn:

1) The usability of knowledge increases alongside the level of maturity of knowledge, and
2) What represents knowledge is defined by the goal of the user, i.e. when (or this happens when) meaning is assigned upon which some action or objective can be achieved.

As such, if for example the objective of the user is to know the level of cholesterol of John Doe then *"240 is the level of cholesterol of John Doe"* could be said that is knowledge rather than just information and the information is then the *"level of cholesterol is 240"*. If however, the goal of the user is to know if John Doe has a high level of cholesterol then *"240 is the level of cholesterol of John Doe"* is just information that coupled with the information that "240 is a high level of cholesterol" the knowledge that *"John Doe's level of cholesterol is too high"* is then created.

As can be observed from the example provided above, the knowledge usability concept is dependent on the 'question + answer' paradigm. It can be said that we have knowledge when we have the answer to a question however, when we just have the answer and no question, what we have is information.

[14] This should be understood as system, system elements or people.

This perspective of knowledge as being something defined through the perspective of the goal of the user rather than independent of it might help clear some of the disputes regarding the concept of knowledge and the relationship between knowledge, information and data. This is not to say that these concepts are interchangeable and that there are no distinctive states of knowledge or that there is no progression of knowledge from lower to higher states, but rather that it might be more useful to look at knowledge as being something used to achieve a stated goal (answer a question) and not as something independent of the goal.

Following the above assertion it could be also said then that for knowledge to become into being, it needs the following:

- Symbols/representations
- Processor (that uses/operates the symbols)
- Goal (of the user of the knowledge)
- Beneficiary

Knowledge therefore can be viewed as a product constructed through the interaction of the above elements. Special consideration has to be given however to the concept of ‘user’ as it has an active and interchangeable role in the construction of knowledge. ‘User’ can be both the processor of the symbols/representations and the beneficiary, who might not have a processing role as the user has. Furthermore, it is more likely that in the real world, this knowledge processing system will have multiple levels and, for example, the goal at a lower level will not be the same as the goal at a higher level, as illustrated through the cholesterol example. This association supports the system perspective of knowledge, i.e. the view that in a system there is a component level and a system level, each with their own goals and functions.

Attributes of knowledge

Regardless of the perspective that one may have on knowledge, what is of use in DSS research is the understanding of the various types of knowledge that can be used and generated by DSSs. These can vary depending on the knowledge attributes.

An attribute is a dimension along which knowledge can vary depending upon a range of values (e.g. age) or categories (e.g. tacit vs. explicit). Holsapple (2008) identifies a list of twenty-three attribute dimensions that include: mode (tacit vs. explicit), type (descriptive vs. procedural), applicability (from local to global), abstraction (concrete to abstract), etc.

Of particular interest in this research is that there are the different types of knowledge, as the interplay among them has long been recognised as being an important feature in the development of DSSs (Bonczek et al., 1981). From the point of view of knowledge type attribute it, can be differentiated between three main categories: descriptive, procedural and reasoning (Holsapple and Whinston 1988, 1996, Holsapple 1995, 2008).

Descriptive knowledge, as the name indicates, is a type of knowledge that describes an object, concept or situation. This type of knowledge can be acquired (from external environment), selected (from internal storage) generated (e.g. derived through analyses, recognition of patters); assimilated and emitted (Holsapple, 2008). Procedural knowledge on the other hand is fundamentally different from descriptive knowledge; it is knowledge about how to do something or how something occurs (Holsapple, 2008). Methods, strategies and action plans are examples of procedural knowledge.

Although procedural knowledge is like descriptive knowledge in that it can be acquired, selected, generated, assimilated and emitted, the manipulation of it and the skills to do it may differ. Furthermore, procedural knowledge can be applied to other types of knowledge to generate new knowledge (Bonczek et al., 1981; Holsapple, 2008).

Holsapple and Whinston (1988, 1996) identify a third major type of knowledge, reasoning knowledge. Reasoning knowledge can specify what option is valid or what action should be taken in a specific situation (Holsapple, 2008). Compared to the other types of knowledge this type is more prescriptive in nature as it offers a conclusion or action to follow. The connection between outputs and inputs in this type of situation is based on logic, analogy, correlation or causality (Holsapple, 2008). As with procedural knowledge, reasoning knowledge can be applied to other types of knowledge to generate new knowledge; however, this new knowledge could be in the form of procedural (e.g. how to reach a goal) or descriptive knowledge (characterisation of a generated diagnostic) (Holsapple, 2008).

Knowledge Management and Knowledge Work Support Systems

While knowledge management research tends to be mainly focused on knowledge creation (Holsapple and Joshi, 1999; Alavi and Leidner, 2001), there are other types of systems that are mainly designed to support decision-making through storage, retrieval and transfer of knowledge. These are referred in literature as Knowledge Work Support Systems (KWSS) and are focused on assisting decision-makers to overcome cognitive limitations when performing knowledge works by facilitating learning, remembering and sense-making (Burstein and Linger, 2003, 2006).

These types of systems introduce a new dimension through which information systems could be differentiated and categorised; that of degree of support that it offers to the decision-maker, which is different from the dimension of type of support that the system offers that was discussed so far. The degree of support can also be understood as the degree of autonomy that the system and the decision-maker have in the decision-making process.

This dimension supports the shift discussed by Burstein and Carlsson from the view of decision support systems as focused on providing solutions for decision problems to a view where the system assists the decision-maker in finding relevant information, which the decision maker can then process and convert into actionable or prescriptive knowledge (Burstein and Carlsson, 2008).

The perspective of DSS as a system focused on providing supporting information rather than solutions perceives the decision-maker as being engaged alongside the decision support system in a joint cognitive process of problem exploration and assumes greater autonomy for the decision-maker in the process (Burstein and Carlsson, 2008). This viewpoint is consistent with the system perspective of knowledge production and assumes that the decision-making system is greater than the DSS. Furthermore, it views knowledge management as a means to an end rather than an end per se (Burstein and Carlsson, 2008).

3.3 Conclusions

To answer the research questions set in Chapter 1, literature relevant to selection of training media, the role of media in training, assessment of competences and development of DSS and management of information have been investigated.

In regards to the first research question, "How can training media be differentiated?" the literature reveals that the LVC (live, virtual, constructive) breakdown is not sufficient to meaningfully distinguish between various types of training media because training devices and environments are more complex and can contain a multitude of media types. The added complexity is because of the various media types that can be combined or mixed into a single training device or equipment (e.g. training aircraft with synthetic targets and simulated weapon effects). This issue, of semantic concern, hinders on one side, communication between various stakeholders (e.g. research community, industry) and on the other, it hinders differentiation or meaningful comparison between various training devices and/or environments.

To be able to differentiate between various training media in a more meaningful way there is need for more research into ways of classifying training media and development of a classification framework to address the multitude of dimensions that characterises training media (e.g. human involvement, media attributes, environment and device attributes).

Investigation of literature regarding the role of media within training (hence 2nd research question: What is the role of media and method in training?) revealed that there are conflicting views on the impact of media on the learning process (process that training is based on). Though overwhelmingly the view is that the method (of learning) is having a more direct impact on learning than the media (hence the extant approaches which are developed around the process: select the method then select media for the chosen method) there is research that suggests that the impact of media on the learning process is underestimated (e.g. Lave and Wegner, 1991; Kozma, 1994, Cobb, 1997). The findings suggest that there is need for more research into the mechanisms through which media interacts and influences the learner/learning process.

One such mechanism of interaction, that seems significant within the literature, is the cognitive route. For example, Kozma's research focuses on the cognitive aspects of media while Cobb's demonstrated through experimental studies that media can provide cognitive efficiency. As such, it could be concluded that media has a direct impact on the cognitive effort undertaken by a learner or trainee during acquisition of new knowledge. Kozma's and Cobb's research emphasis that how something is learned is as important as what it is learned and that the form in which information is delivered (aka the medium) is not just a passive mechanism but an active one, which has direct impact on how the information is going to be cognitively processed.

These findings, i.e. the suggestion of a cognitive mechanism of interaction between media and learner, support the research investigation into mapping the relationship between training media and the trainee. Furthermore, the mapping could be extended to incorporate the connection between method and trainee.

As undisputable stated within the literature, the method(s) and/or instructional process is another key component in any selection of media for constructing training programmes. However, there is no unified framework on how the process of selection of methods and construction of instructional methodology should be followed.

The literature review reveals though there are a multitude of ways that one may go about this selection process and various frameworks have been developed. These are in the form of: instructional events list (Gagne, 1997), methods of instruction list (Sugrue and Clark, 2000), list of principles (Salas and Cannon-Bowers, 2001). Though there are some differences between these lists, there are also sufficient similarities between them that could allow for use of the lists to develop a unified process framework for instructional method selection. This could provide more uniformity across the training (as discussed in Chapter 1, subsection 1.3.3 Industry needs, the lack of uniformity was registered as being an issue for the industry).

To answer the 3rd research question, that of how can the differences between trainees previous experiences be identified, extant literature in the area of assessment of competences has been reviewed. This has revealed that although there are methods and techniques such as TNA (Training Needs Analysis), Gap Analysis and MECs (Mission Essential Competencies) that are good for extracting and documenting the trainees' knowledge and skills gaps, this techniques and methods do not take into account, in an integrated way, the level of proficiency and context.

These dimensions (level of proficiency and context as well as competency) are important to fully understand the specific gaps in knowledge and skills that a trainee might have (DeCoi et al., 2007) such that tailored training can be constructed and delivered to the trainee. So far, MECs seems to be the only technique that addresses partially the dimension of context (through environment and experiences) though is very task orientated and does not take into account factors such as platform operated and previous experiences. Furthermore, studies that look at use on MECs revealed that there are inconsistencies regarding the level of breakdown of dimensions and issues with the links between the dimensions (e.g. Symons et al., 2006).

The factors such as, platform utilised to acquire a skill and other details that characterise the trainees previous experiences are important because training programmes are constructed based on training needs that are identified based on the operational environment, the context (hence the TNA importance). Therefore, the question of how to capture these gaps remains unanswered.

To answer the 4th research question, that of how the information resulted from TNA could be managed, extant knowledge in the area of development of DSS (Decision Support Systems) and management of information have been reviewed. Furthermore, this area is of particular interest in this PhD because of the overall aim of this project, which is to provide decision support solutions.

The review of literature revealed that there are a multitude of types of DSS with a variety of functionalities. This diversity steams from the diverse theoretical background that underpins the development of DSS, which can range from psychology theories to system science theories. Furthermore, DSS are easily confounded with MIS (Management Information Systems) though the argument is that a DSS would provide more than a system that manages information, a DSS would support the decision-making process itself (Parker, 1999).

Looking at the literature concerned with the attributes (or characteristics) of DSS it was found that there are two main dimensions that a DSS could be characterised through: the type of problem that it is used for (e.g. structured vs. ill-structured), and the level of support that it provides (e.g. it can assist decision-makers to overcome the cognitive limitations through analysis of large amount of information and providing alternative solutions, or support the decision-maker find the relevant information that he or she can then covert into actionable information) (Holsapple, 2008). Furthermore, the literature review revealed interesting aspects that have to do with knowledge construction and usability, which highlights the importance of decision-maker in the process, and the type of knowledge that it can provide (e.g. descriptive, procedural, reasoning). As such, the decision-maker is in a relation of collaboration with the DSS in a joint cognitive process (Burstein and Clarsson, 2008).

All these principles that characterise knowledge construction and use, which are integrated part of any DSS, are utilised and incorporated within the research conducted to provide the support solutions.

Chapter 4

Research outputs and developments

This chapter presents the outputs of the research conducted in this PhD project. The chapter is split into five main sections, each highlighting the research outputs pertinent to each of the four research questions defined in the Introduction chapter and ends with a summary section.

As such, section 4.1 Training Media Breakdown, presents the outputs concerning development of a multidimensional framework to support classification of training media. This section describes the research work done in classifying the training media environments (subsection 4.1.1), classification of training media equipment (subsection 4.1.2) and the development of the classification framework of training media (subsection 4.1.3).

Section 4.2 Training media and the method, presents the research outputs that address the second research question, which is concerned with identifying the role of media and method in training. In this section the research conducted in understanding the relationship between this elements that underpins any learning and training activity as well as models that map the interactions between them are presented (subsection 4.2.1). Furthermore, in this section, a new strategy for selection of training media is presented in subsection 4.2.2 and a unified framework for selection of instructional process in subsection 4.2.3.

Section 4.3 presents the method and the concept tool developed to identify the differences in trainees' competences and Section 4.4 presents the method and concept tool developed to capture and present the TNA outputs. The chapter ends by summarising the research presented in this section (section 4.5 Chapter Summary).

4.1 Training Media Breakdown

"The purpose of taxonomy is to present an ordered classification, according to which theoretical discussions can be focused, developments evaluated, research conducted and data meaningfully compared" (Milgram and Kishino, 1994)

As discussed in the introduction of this thesis, the next generation of military training environments is foreseen to be one that will encompass a multitude of media technologies that will provide a safe, cost-effective and high performance aircrew training. This will be a combination of live military assets, virtual systems and other forms of computer-based systems.

The objective of the research presented in this section is to explore the concept of having a multitude of media types, from live to constructive, or real to synthetic within the same training exercise environment system and to propose a classification framework for training media. The perceived need to develop a classification framework arises out of experience from dealing with the LVC media breakdown concept in the present research; as related to the military aircrew training domain, with respect to which parallel issues of inexact terminologies and unclear conceptual boundaries regarding LVC media exist in the field of academic research and industry alike.

The classification framework presented herein is motivated by the need to distinguish between the various media technologies used for design and development of training systems.

A hierarchical view of training media

In the aircrew training domain, media and technology has a multitude of meanings, all of which are associated with the basic understanding of the media concept. For example:

Media[15] *= the means through which training methods are applied (JSP822, 2012); an object or device on which data is stored (Computer Science); a surrounding environment in which something functions; a technique or means of expression as determined by materials used or method involved (Art); the materials used; technology that appeals to human senses*

Technology[16] *= the application of scientific knowledge for practical purposes; machinery and equipment developed from scientific knowledge*

In simple terms and according to the definitions, it can be said that media is a type of technology (means or machinery) that appeals to the human senses. Also, with application to the training domain, three main categories of the media are prominent:

- Media as means
- Media as device/equipment
- Media as environment

For example, the TV appeals to seeing as well as hearing. As mentioned above, training equipment can and does encompass a multitude of types of media elements from real to constructive and the environments can be constructed by a multitude of media, equipment and technology. Therefore, it can be concluded that the relationship between media, equipment and environment is hierarchical and that these three categories are subordinated, such that the environments contain the equipment(s) and the equipment contain the media which appeals to the senses (Media ⊃ Training Equipment ⊃ Training Environment) (Ciocoiu et al., 2012).

4.1.1 Classification of Training Media Environments

With a specific focus on Training Environments, cross-referencing of the hierarchical subordinated media categories with the way media can be distributed across these

[15] The meanings have been selected on the basis of what instances were found to be pertinent to the aircrew training domain
[16] The meanings have been selected on the basis of what instances were found to be pertinent to the aircrew training domain

categories infers that there is a possible LVC media blend within each category. This can be expressed in a hierarchical model of LVC Training Environment (Fig. 4.1).

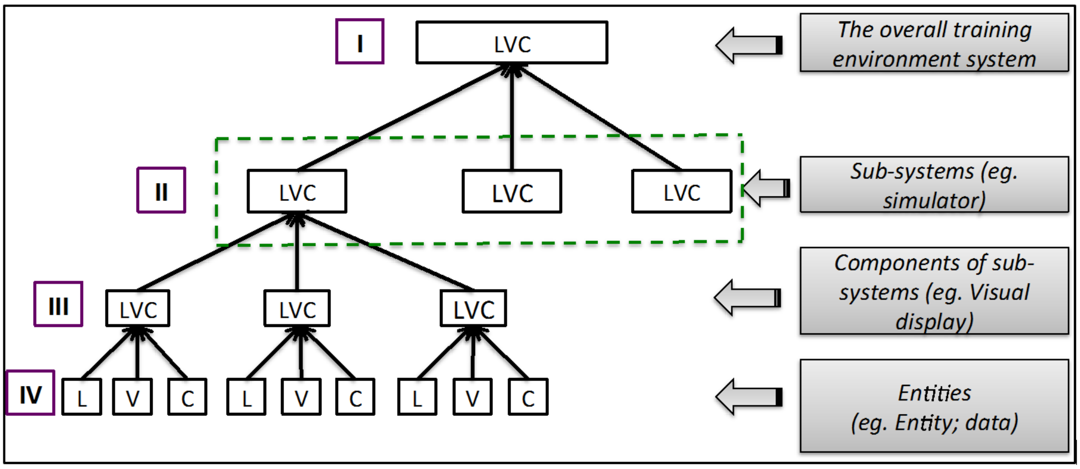

Figure 4.1. The LVC Training Environment

In Figure 4.1 there is a clear separation between what constitutes the media (III), equipment (II) and environment (I). However, in practice, there are instances when the equipment makes up the entire environment of a pilot, like for example, a simulator. In other words, the training equipment becomes the training environment.

To better understand this relationship between the environment and the equipment and to be able to grasp the implications of this relationship, an in-depth look at what the environment and the equipment means is required. For example, when different stakeholders speak of the training system, do they mean the training environment or the training device?

According to the International Council of Systems Engineering (INCOSE):

> *"a system is a construct or collection of different elements that together produce results not obtainable by the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, and documents; that is, all things required to produce systems-level results. The results include system level qualities, properties, characteristics, functions, behaviour and performance. The value added by the system as a whole, beyond that contributed independently by the parts, is primarily created by the relationship*

among the parts; that is, how they are interconnected" (Rechtin and Maier 2000).

The differentiation between a training environment system and a training equipment system is important for a Systems Engineer as these types of systems may have different characteristics and therefore pose different challenges. For example, while training equipment system or device can be considered to be a more traditional, technological type of system, where the integration of the parts is important, the training environment can be considered to be more akin to a system of systems where interoperability between the system-parts plays a key role. Therefore, the setting up of a training media environment system may not only be a matter of identifying and selecting various training equipment systems (sub-systems) but can become a matter of constructing and managing a system that comprises a mix of media technology systems (Ciocoiu et al., 2012).

The LVC concept is frequently used in association with a variety of types of environment-systems that do not always fit exclusively in any of the L, V or C category. Although the definitions of various types of training environments found in the literature (Appendix 7) appear to make a reasonable delineation between the types of training environments, when it comes to use, analysis, research and implementation, the distinctions quickly become clouded.

However, the definitions contain specifications regarding the components found in the environments, such as people, effects, elements, equipment and the pertaining (physical) environment. These components can be, depending on the case, real or synthetic. On this basis a basic understanding about the different types of environments can be achieved. This relationship is expressed in Figure 4.2.

Env.	Eq.	Eff.	El.	Training Environment		
R	R	R	R	Live	Live Environment	
R	R	RS	S	Augmented Reality		MIXT
R	R	S	RS	Live Simulation	Synthetic Wrap	
S	S	S	RS	Virtual Simulation		ENV.
S	S	S	R	Augmented Virtuality	Synthetic Environments	
S	S	S	S	Constructed Virtuality		

Fig. 4.2 Basic classification of Training Media Environments

(Decomposition of training environments based on primary environment (Env.), Equipment (Eq.), Effect in real life (Eff.) and elements – the decomposition is based on L,V and C media definitions included in Appendix 7)

In Fig. 4.2 the components of environment (Env.), equipment (Eq.), the effects (Eff.) and elements (El) that are real are expressed as "R" and the synthetic ones as "S". The table in the figure shows what type of elements (real or synthetic) the various training environments contain.

The Mixed Environments from Fig. 4.2 can be compared with the Mixed Reality Environment concept that Milgram and Kishino (1994) described in their research on taxonomy of video displays (Fig. 4.3). The idea that Milgram and Kishino put forward, however, is that all these environments are placed on a virtual continuum where any type of environment sits somewhere between a Real and a Virtual environment.

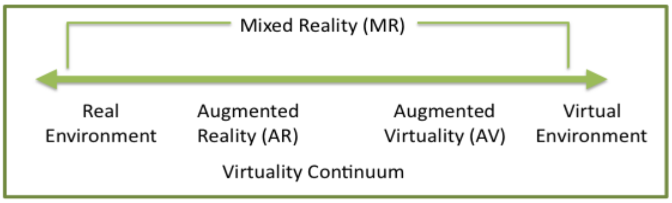

Fig. 4.3 Simplified representation of a 'virtual continuum'
(adapted from Milgram and Kishino, 1994)

However, in the military training aviation domain, the 'Constructive' concept is also present. This is defined as something created purely within computer systems ~~and with~~ (see Appendix 7). These are usually war games, used for strategy and tactical training. As the concept 'Virtual' refers to a simulation, which means that something is not real but is made to appear real and can contain realistic as well as non-realistic elements, it can be said that 'Constructive' is different from 'Virtual' because it contains only non-reality elements (e.g. future warfare scenarios). Therefore, it can be assumed that 'Constructive' sits at one extreme of the Mixed Environments continuum, opposite to real, while virtual, sits somewhere between real and constructive. This is expressed in Fig. 4.4.

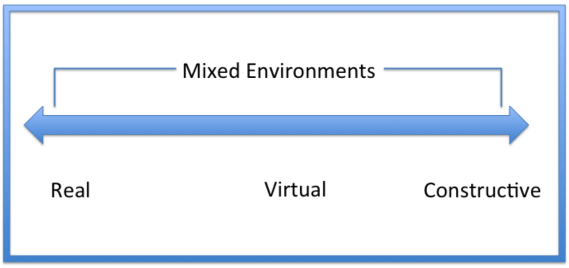

Fig. 4.4. Mixed Media Environment Continuum

In their paper on taxonomy of visual displays Milgram and Kishino (1994) made an interesting and valuable observation. Synthesised images of non-existing (virtual) objects can be made to look extremely realistic, however, *"just because an image looks real does not mean that the object being represented is real"*. This can be valid for environments as well, and therefore any terminology that is employed within training media systems must be able to reflect these differences.

To help with these differences, it makes sense to look at the domain that is heavily involved with the realisation of training equipment's and environments. That is the computer technology domain. By looking at how they understand some of the media concepts we will hopefully get some more clarity into the issue.

Therefore, looking at the use of terms related to media within the computer technology domain the following was observed:

Synthetic *means* **Realistic** + **Virtual** (elements and data)

Simulated *means* **Realistic**

Virtual *means* **Computer Generated**

Augmented Reality (AR) *means* **Synthetic**-in-**Live**

Augmented Virtuality *means* **Live**-in-**Synthetic**

Realistic *does not means* **Reality**

Reality *means* **Live**

These relationships can further help to classify various types of training environment systems and offer a better understanding of what is, or is not, included in any class type of environment systems. The training environment system classes are presented in Fig. 4.5.

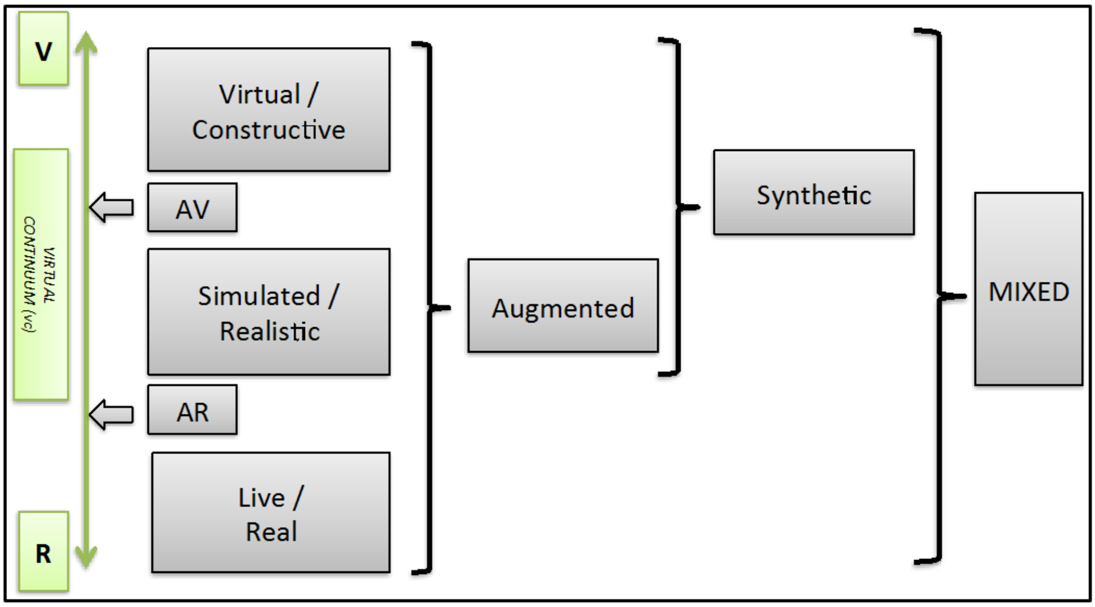

Fig. 4.5 Classes of LVC Training Environment Systems

4.1.2 Classification of Training Media Equipment

LVC training media has been mostly a technology driven affair, in which the LVC blend is a smorgasbord of technologies; existing, as well as to be developed. However, these technologies (old and new) need to be able to adapt to training requirements and to do so they also need to be able to be used in scaled-down subsets (van der Pal., 2011). That is to say, at the level of a system-element (Fig. 4.1).

In the aircrew training domain, the process of selecting training media equipment and the design and development of the training media environment is dominated by an information flow loop between the training needs analysts and the training design and development engineers. From discussions with SME's (Chapter 1, Section 1.3: Problem Space) it became clear that although this relationship is essential for the choice of what training systems are going to be employed in training, there is a communication barrier between setting the requirements and realisation of the training system, either that appertain to the live or to the synthetic domain.

When it comes to defining the training environment, which is at the highest level of abstraction within a training system, a classification based on L, V, C types may be sufficient. In fact, it might be hard to achieve and potentially pointless to probe deeper at this level because when working at this level of abstraction, details are deliberately suppressed in order to avoid communication at the environment level being cluttered by specifics on equipment and media. However, when it comes to training equipment, distinguishing only between different types of media it is insufficiently insightful to be able to make an assessment from which to derive a decision on employing different training systems. At this level, the judgement process is not focused on the media type (L, V or C) because other variables become more prominent. This is highlighted by the fact that although various training equipment's might be grouped in the same media category, they do not have the same quality and, therefore, they do not offer the same output. For example, simply stating that training should be taken place as: "30% in live, 50% in simulator and 20% in classroom" (e.g. MMST tool discussed in the Introduction chapter), does not offer enough information to definitively specify the training, because not all live, simulators and/or classroom training is the same.

Fidelity is mainly considered as a way to measure the capability of a synthetic system in relation to the live/operational environment, but when it comes to compare simulators the relevant question is whether they are of *"equal value"* (Kirby et al., 2011). A significant amount of resources are being invested in developing technologies that will enable various training systems to look and feel real, *"where* *the standard comparison for realism is taken as direct viewing (through air or glass)"* (Milgram and Kishino, 1994) or also known as *"unmediated reality"* (Naimark, 1991a).

Fidelity is usually considered to be an attribute of quality, but recent discussions have included immersion as something distinct from fidelity though in earlier research, immersion and quality are described as dimensions of realism (Milgram and Kishino, 1994). Fidelity in relation to the real-world environment should include both immersion (presence) and quality as dimensions, instead of fidelity referring just to 'look-alike' and 'feel-alike'.

Fidelity however, is just one of the different variables that are taken into consideration when it comes to making judgements between various training systems. Therefore, the question is: what are the most significant dimensions of the training equipment that will offer insightful and helpful information for decision-making with regard to choice of training equipment?

What is known about the training equipment beside media and fidelity?

Another important aspect when it comes to classification and meaning with regards to training media is that the same 'object' can be real and non-real at the same time, depending upon from which position it is viewed. For example, something that is real for the trainee can be non-real for the training designer. In this case, the 'viewers' have different knowledge about the same 'object' and/or 'world'. This paradigm is presented in Figure 4.6.

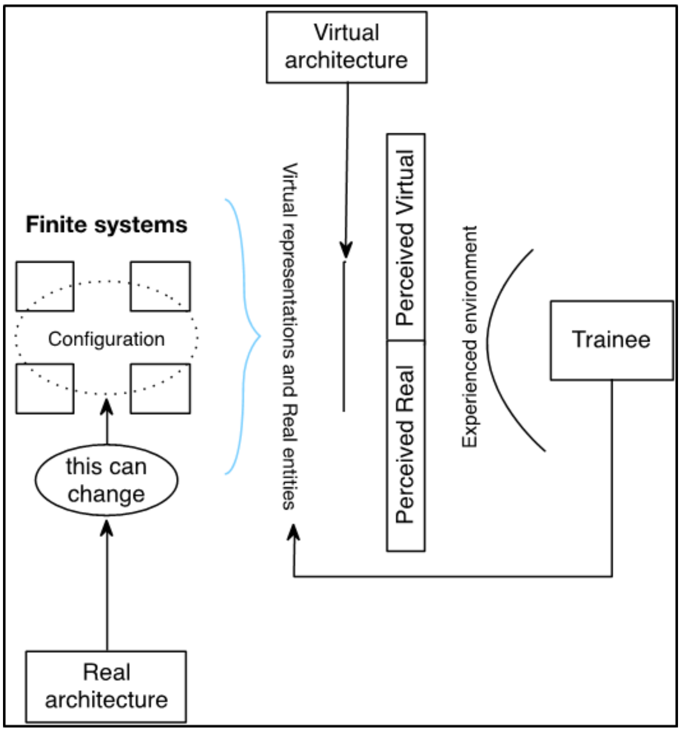

Fig. 4.6 Components of the Training Environment System

Figure 4.6 shows the trainee and the training designer experience of the same environment. The system in real life, or as experienced by the trainee, would have elements that would be perceived as virtual or real. However, from the point of view of the training designer, the system would be a representation of the real system, like a model, where every component, which the trainee may experience as either virtual or real will be virtual for the designer.

A training equipment/device in itself, when is not in use, does not display any capability; it is inert. However, when it is in use, its capabilities come into being, as capability is a construct realised only in action (Dalton, 2013), and when a training device is used, a method is automatically attached to it/ embedded in it (mainly through the way it is interacting with its environment, including the human).

Method in this case is understood as a *"technique for performing a task…"* (Martin, 1997); a way of doing things. This 'method' is different from the 'instructional methods' that are directed strictly on techniques of how to learn and where specifications on how to use (manipulate) the training devices are given.

Training media technology represents a multitude of devices and methods used for training, therefore, one dimension that is essential to any breakdown attempt will be the training media equipment potential to influence any learning-cognitive relationship (learning will ensure that capabilities of a real-world/operational equipment are enabled).

As was mentioned in the Literature Review chapter there is the debate concerning if, and how, media influences learning (Clark, 1994 and Kozma, 1994). This debate has been active for at least two decades with no major breakthroughs. However, regardless of whether media directly influences the learning process, it is clear that media devices possess features that interact with the human senses, such as, for example, image, sound, and motion, and these features do influence the cognitive process. The cognitive processes can be directed in a structured way, which is the 'instructional method' to achieve learning. Therefore, whatever side of the debate someone is on, it can be assumed that there is common agreement that the training equipment does possess cognitive-related attributes. These can be sense-related and method-related attributes.

These cognitive-related attributes are supported by the technology that training equipment (media) possesses. These can be a 'hard' and/or a 'soft' component. In this context a 'hard' component of training equipment refers to a physical (something you can touch) component, while 'soft' refers to a metaphysical component (it exists but there is no physical form of it). Classic examples of these types are the computer hardware and software elements.

Because the 'hard' and 'soft' components can be acquired and used separately, each can be considered as being training media. This distinction is important as they may have different attributes associated with them. For example, a PC without any software is merely a device that has the attributes to support various types of operating systems that can, in turn, support a limited type of software programs.

The way that the 'hard' and 'soft' training media can be connected between, and within them, is a matter of technical capability. This can be considered to be the media technical attributes, which are related to networking, integration and interoperability dimensions.

Last, but not least, every training equipment will also have a cost associated with it. Therefore it can be assumed that there is a cost attribute dimension related to any ‘soft’ or ‘hard’ training media. Costs can be further broken down into development, implementation and support-associated costs.

4.1.3 Training media – The Classification Framework

In summary, any training media equipment, ‘hard’ or ‘soft’, can be characterised by three dimensions: cognitive, technical and economic. The inclusion of all three attributes will enable a better understanding and differentiation of training media and facilitate communication between various domains that are concerned with the issue of training specification. The relationship between the discussed concepts as well as the proposed classification framework are presented in Figure 4.7.

Rather than relying on the fuzzy construct of Live, Virtual and Constructive, an attempt has been made to investigate and examine some of the essential characteristics that can help distinguish better between different training media. The main purpose of the taxonomy presented in Figure 4.7 has been to shed some light on the terminology issues, in order that investigations and developments carried out by training managers, developers, and designers, among others, can have a point of reference, which will allow comparison of similarities and differences between various research activities.

The factors described above are not those that directly influence the decision process for choice of media for training, but the factors that affect the classification of and, therefore, the differentiation between training media. A classification is essential, in any discussion that involves decision-making on selection of training media, the reason being that, when it comes to deciding which media to use for a particular training need, there are other considerations to take into account (as specified in the requirements), that depend on precise specification. A less precise classification of training media, such as L, V and C will be insufficient, as there can be a variety of requirements that can satisfy a given requirement.

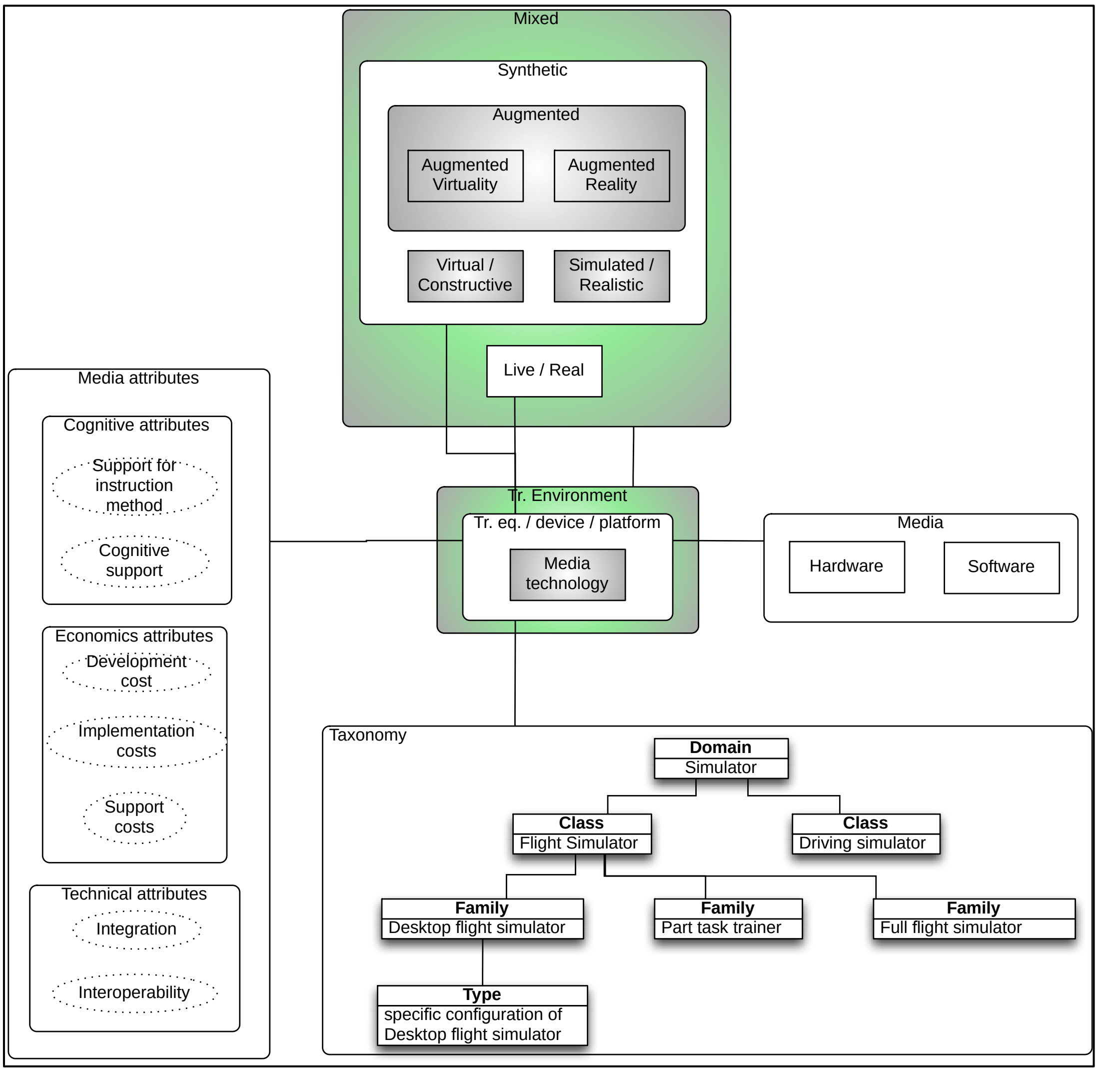

Fig. 4.7 Training Media Classification Framework

The Training Media Classification Framework is visually put into context in Figure 4.8, illustrating the stakeholders, the input and outputs of the framework and where in the training lifecycle it can be applied. The training development lifecycle shown is based on DSAT process (MOD 2008) (Full DSAT process is shown in Figure 1.3)

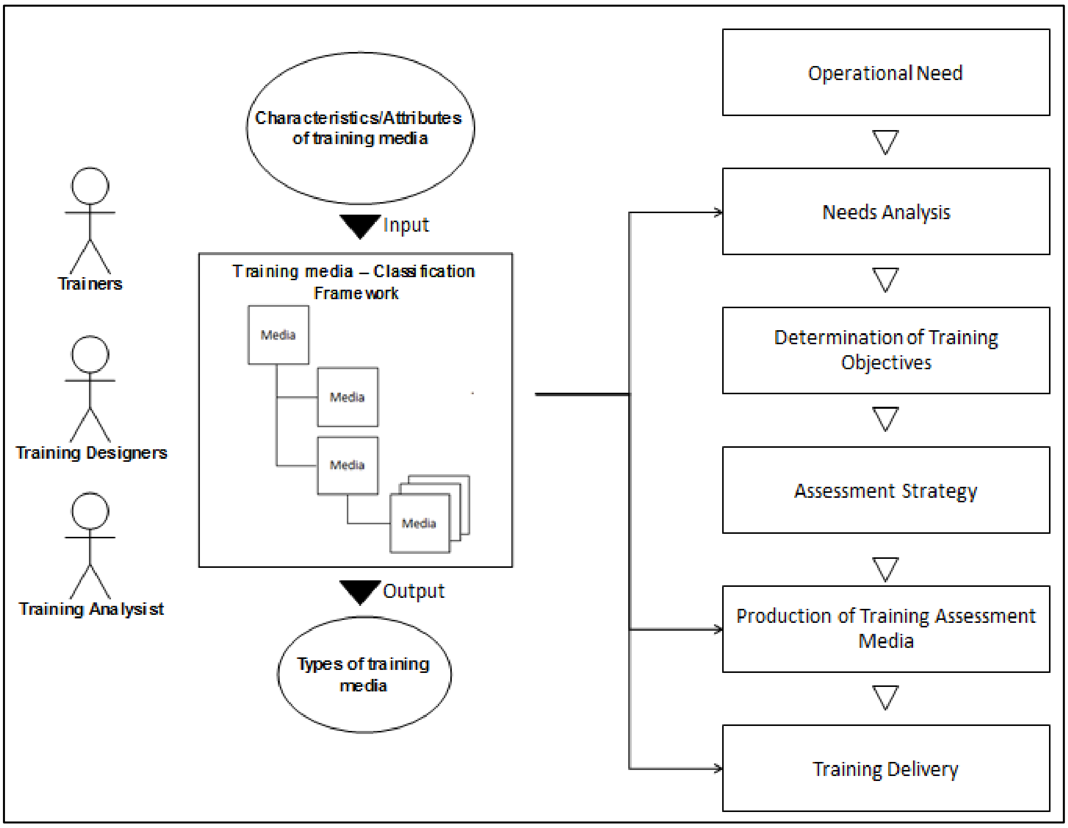

Fig. 4.8 The Training Media Classification Framework illustrated in the context of stakeholders, input/outputs and the training development lifecycle.

4.2 Training media and the method

4.2.1 Media, the learner and the method – a cognitive model

Kozma (1994) proposed that media should be analysed in terms of its cognitive relevant attributes or characteristics. These attributes are divided into:

- Surface characteristics: the **technology** (which is also considered to be the characteristic that determines the function of that medium)
- Internal characteristics: the **symbol system** and the **processing** capability of the medium

These characteristics and the relationship between them are illustrated in Figure 4.9.

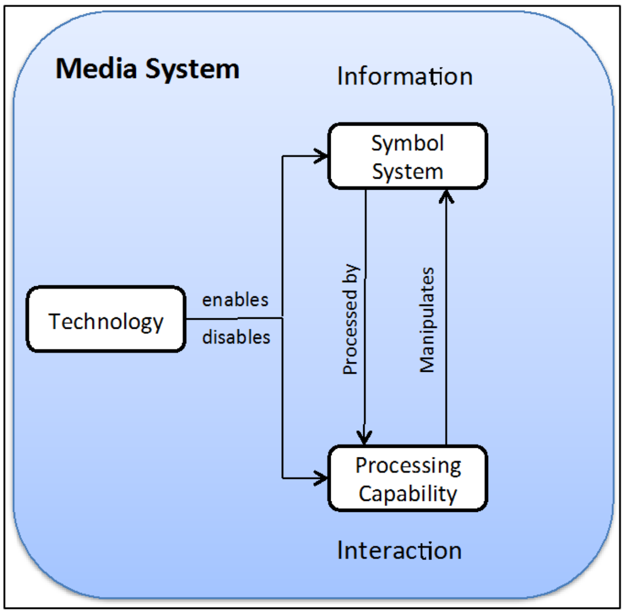

Fig. 4.9 Media – the cognitive perspective (as described by Kozma, 1994)

Kozma's view illustrated in Fig. 4.9 is based on Salomon and Goodman's research (in Kozma, 1991), which shows that there is a relationship between a medium symbol system and a mental representation. The cognitive representation of media allows comparison analysis with the human cognitive system, where information is retained in our memory in various types of mental schemas that are manipulated through various mental strategies. The media internal features (symbol system and processing capabilities) form (or construct) representations similar to the mental schemas necessary for learning, which learners make for themselves within the cognitive system during the learning process. Since media can perform some of the underlying processing operations for the learner (e.g. hand calculator that does multiplications), we can see how media could be used to increase the efficiency of the learner's cognitive process as proposed by Cobb.

Although Cobb concentrates on proving the importance of introducing the "cognitive efficiency" dimension into research, or what he calls "provisionally links media to learning", he also does not dismiss the possibility that media may create cognitive products, such as concepts, schemas and mental models.

As it is known that the cognitive system has a limited capacity in processing and acquiring information (e.g. cognitive model and chunking theory – in Cognitive Psychology domain) nevertheless, information is more easily assimilated if it is organised into meaningful chunks. Media can be used exactly for this; with the help of media, complex information can be organised and compressed so it become more cognitively easily to access and acquire.

Cobb (1997) gives examples of how external symbol systems (incorporated in media) can replace human cognitive work by comparing Arabic with Roman numeral multiplication and Chinese versus Roman script. Cobb argues that Arabic notation is cognitively efficient for multiplication because it supplants some of the cognitive work involved, and Chinese character allows faster reading because the mind processes shapes and picture faster than it does graphemes. However, Cobb also points out that initially, learning Arabic numeracy and Chinese script, take much preparatory learning compared with learning Roman script and numeracy; i.e. he talks about short versus long term efficiency trade-offs, and points out that choosing one or the other is a case of "media selection".

In terms of the human cognitive system, the mental schemas and the mental strategies to manipulate the mental schemas are enabled or disabled by the internal cognitive ability of the individual. This could be represented in a model similar to the one that depicts media from a cognitive point of view (Figure 4.10).

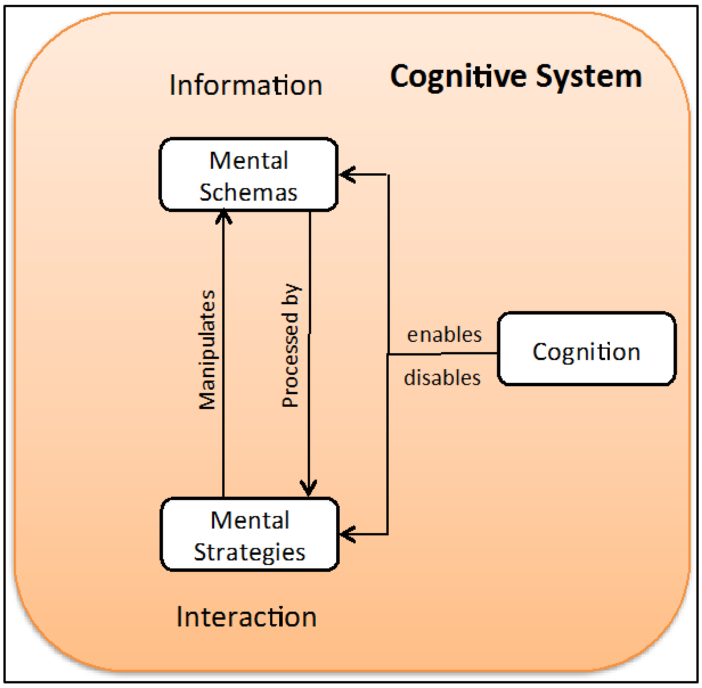

Fig. 4.10 Learner – proposed cognitive perspective

Examination of the two cognitive models of media and the human cognitive system shows that there is a common, or overlap, area between the two systems, the storage of information and manipulation of this information. These are functions possessed by components of both systems (media and learner).

Examining further models of communication and information processing such as the Hollnagel and Woods (2005) Extended model of communication that is based on Shannon-Weaver Model of Communication (Figure 4.11), which represents a two-way communication model between systems, a model of interaction between the media and the human can then be drawn. (Figure 4.12).

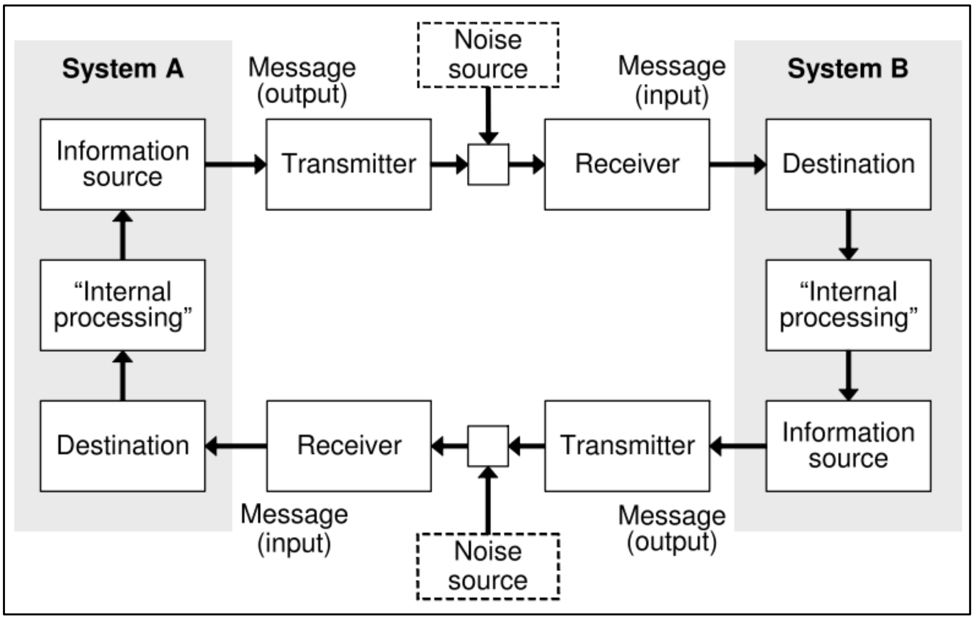

Fig. 4.11 The extended Shannon-Weaver model of communication (as depicted in Hollnagel and Woods, 2005)

The Hollnagel and Woods model shows how communication between systems, regardless of whether they are technical or human, happens and what are the main elements that enable that communication to happen. Their model shows how a message/information is delivered via external interaction channels and how the message is processed internally by each system through an "*Internal processing*" component. The communication between the media and the human cognitive system can be mapped in a similar manner, as is shown in Fig. 4.12.

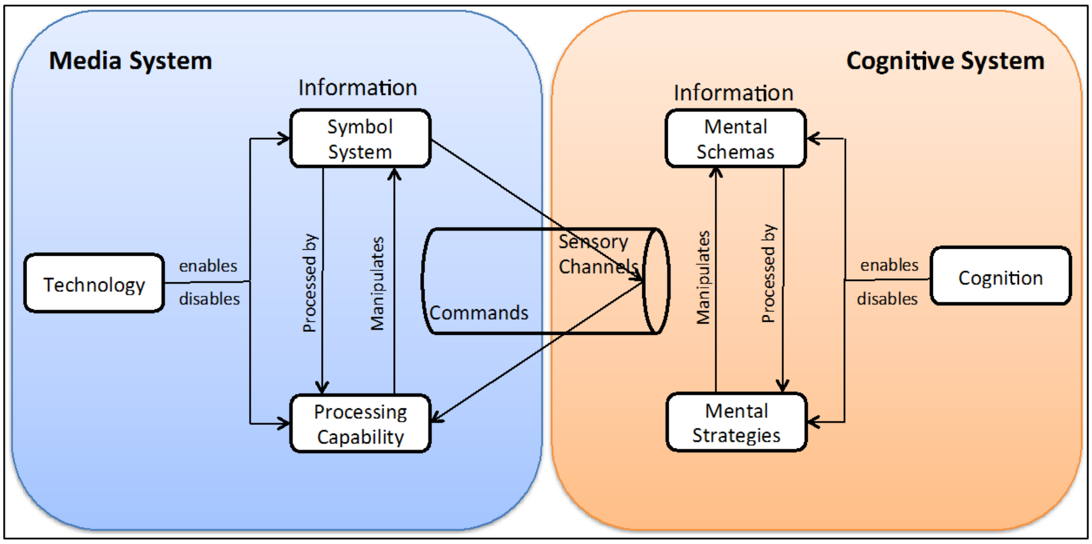

Fig. 4.12 A Cognitive perspective of the interaction between media and the learner

As presented in Fig. 4.12, the human cognitive system receives and transmits information from/to the environment via the sensory channels (seeing, hearing, tactile, etc.) and the media system receives information from the environment via the sensory channels (earing, hearing, tactile, etc.) and the media systems receives information from the environment via commands. These are external communication channels and correspond to Transmitter/Receiver elements of Hollnagel and Woods model of communication. The internal communication channels, the Processing Capability (for media) and Mental Strategies (for human) correspond to the "Internal processing"; the Destination is represented by the Technology and Cognition and the Information source by the Symbol System and Mental Schemas which are enabled or disabled by the technology/cognition.

What the model of Media-Human interaction presented in Fig. 4.12 shows is that while physically the two systems are separated, functionally they have similar properties. This paradigm is expressed in the Joint Cognitive Systems literature as functional non-separateness, which basically see the functions of the two systems as being as one (Hollnagel and Woods, 2005).

The model presented in Fig. 4.12 should not be interpreted as implying that there is a single functionality expressed by two physically distinct systems but that there are two complementary functionalities exhibited by distinct physical components. For example, although the media system can transmit a certain mental model (its symbol system) the cognitive system must interiorise that information, through building its own mental schemas in which it integrates the information received, i.e. there is not an automated replacement process where the same function is performed interchangeable by either the human or the media components but that there is a conscious endorsement process of the presented information; endorsement needed to be performed by the human cognitive system. In other words, the learner has to understand, accept and integrate the information within a mental schema. For example, a hand calculator can perform multiplication and that saves a lot of time and cognitive effort. However, if we do not have the concept of multiplication and do not understand the meaning and use of the numbers, it is hardly going to contribute to any learning process.

Kozma (1994) also advocates that it is not the processing system alone that has a cognitive effect, but that the possibility of processing the symbol system, which the learner can manipulate (to the extent that the technology allows) that contribute to the cognitive processing of the information (making of mental schemas) and that this cumulated relationship has a cognitive effect.

Clark (1994) and other researchers that developed approaches and tools for media selection, which were presented in the Introduction chapter (Chapter 1) advocate a unidirectional relationship between media and instructional method, such that media is chosen to support the instructional method. Kozma (1994) however, suggest that media also influences the instructional method and that media can help at developing new methods.

Kozma illustrates his point through the ThinkerTool example, in which media with the instructional method embedded within the tool created a sufficient system for learning to occur. This does not support the point of view that media possesses unique attributes that are necessary for learning, but that the attributes (that can be embedded within a variety of media or media combinations) are facilitating the learning process in an efficient manner; those improving the learning outcome. This point is in line with Reiser’s (1994) view that specific attributes of media make certain methods possible. The concept is illustrated in Figure 4.13.

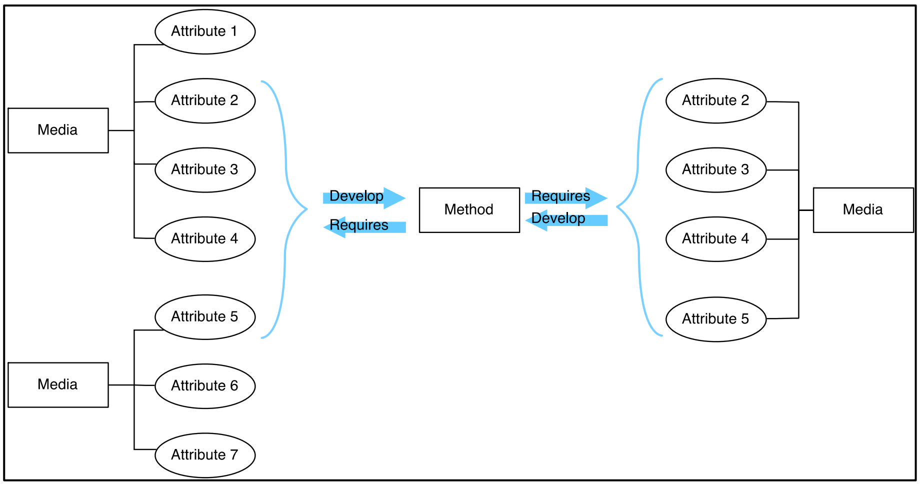

Fig. 4.13 A view of the relationship between Media Attributes and development of Instructional Methods

Fig. 4.13 shows that it is not necessary for the same media (e.g. projector), that contributed to the development of an instructional method (e.g. demo), to be used in the learning process, because other media (e.g. TV) or mixes of media might already have the required attributes (e.g. screening capability) to support that instructional method. The important point here is that the media has the attributes to support the required capability needed by the instructional method. This approach might help not only in the development of methods and in the selection of extant media resources that one has at one's disposal but also for exploring the variety of 'off the shelf' existing media that have not necessarily been designed for the educational process.

The point of view that media contributes to development of methods is supported even by researchers (Reiser, 1994; Shrock, 1994; Mayer, 2003) that argue that media does not influence the learning process. For example, Mayer (2003) who demonstrates that with the same method a variety of media can be employed concludes that *"media are relevant to the extent that some forms of technology enable instructional methods that are not possible with other media*" though "*the principles of instructional design do not necessarily change when the learning environment changes"*.

Mayer (2003) explains why similar instructional methods work across various media; he suggests that this is because the cognitive processing system remains constant across various media environments. Although that is true, this does not explain why some methods are more efficient than others.

A possible explanation might be that of Reiser (1994) that if the appropriate media is not used the method can become ineffective. If we just concentrate our efforts on developing methods based only on how the cognitive system processes information and then search for media to support those methods and do not take into consideration media developments, there is the danger we might miss the opportunity to develop new, more efficient methods.

Following his research, Mayer (2003) concludes that *"media environments do not cause learning, cognitive processing by the learner causes learning"* but if we look at the commonalities between some of the capabilities of media and learner (Fig. 5.4) we can see that media has the capability to perform some of the processing for, and with, the learner. Just because the instructional technology does not change the fundamental nature of how the human mind works, this does not necessarily mean that the cognitive process cannot be aided by appropriate use of technology through instructional method or strategy. Furthermore, as Cobb (1997) argues, media becomes effective in the learning process when it contributes to a learner cognitive efficiency.

Salomon (1979/1994) defines instructional method as *"any way to shape information that activates, supplants or compensates for the cognitive processes for achievement or motivation"*, to which Clark (1994) adds *"Method is the inclusion of one of a number of possible representations of a cognitive process or strategy that is necessary for learning but which students cannot or will not provide for themselves"*. Kozma (1991) argues that "*the medium enables and constrains the method; the method draws on and instantiates the capability of the medium*". Here a parallel can be drawn with the cognitive definition of media. If the technological characteristics of a medium enables or constrains the symbol system and the processing capabilities and the medium enables and constrains the method, then the method shares with the medium the symbolic system and processing strategy.

Based on the rationale presented regarding the functionality and communication relationship between media and the cognitive system and the definition of instructional method, the model presented in Fig. 4.14 has been developed.

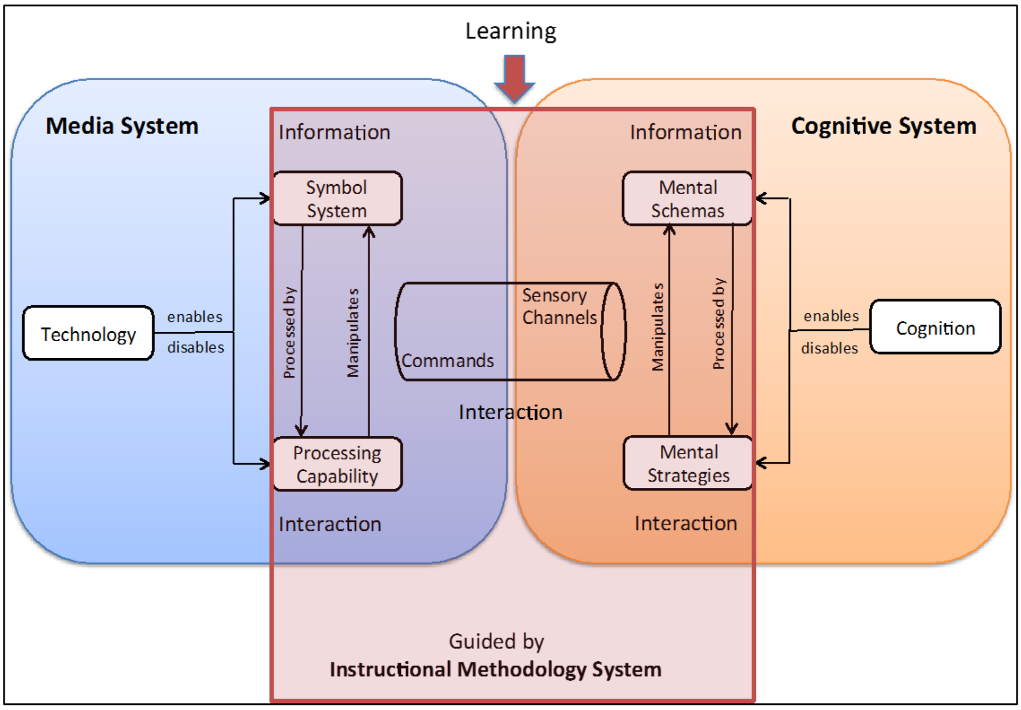

Fig. 4.14 Mapping the interactions between

Training Media, the Learner and the Instructional Methodology – A cognitive model

It has to be noted though that Clark (1994) points out that the instructional methodology is the essential part that ensures learning by supporting the necessary cognitive processes and that whenever learning occurs a medium, or a mix of media, must be present, the role of media is a delivery mechanism that through its attributes supports the instructional methodology. This view is widely accepted within the community. Furthermore, Clark argues that studies that claim that the media influences learning are confounding the media with the method and that they do not control for method.

4.2.2 A new strategy towards Training Media Selection

When selection of media or instructional methods is considered, usually similar factors are taken into considerations (Shrock, 1994). Literature reviews of instructional strategies, instructional methods and selection of training media (Reiser and Gagne, 1983; Romiszowski, 1998; Reynolds and Anderson, 1992; Heinich et all., 1996; Sugrue and Clark, 2000; Lee and Owens, 2001; Pike and Huddlestone, 2011; Melton and Bahlis, 2013) shows that as well as the question of choosing the 'right' blend of media, there is also the question of choosing the right 'blend' of method.

Furthermore, when reviewing the factors that influence choice of method and choice of media it was found that they are very similar. These can be grouped into three categories:

- Audience (developmental level; previous knowledge)
- Objectives (learning objectives; training objectives; level of expected competency following training)

These factors are grouped in Table 4.1. It is quite a complex task to control for method when there are overlaps between them.

Categories of factors	Method	Media
Objectives	- What the trainee needs to know to succeed - Subject matter content - The objective of the lesson - What we want to teach - What are the expected competences - What level of competences is expected	- Objective of tasks - Training objective - Learning objectives - Information types to be transmitted - Response types to be expected - What the audience will be able to do as a result of instruction - The degree of accepted performance - The conditions under which trainees are going to perform - Instructional goals - Course content (form, novelty-complexity) - Feedback (form, content, timing)
Audience	- Who are we teaching - Level of the student - What the student already know - Learning styles/preferences	- Trainees motivation - Skills - Proficiency - Attitudes - Abilities - Resistance to change - Speed and accuracy of performance - Attention span - Experience - Culture - Size - Location - Value of trainee time
Resources	- Available people to support the instructional process - Time - Space - Material resources - Physical setting	- Costs (development, hardware, administrative, management, delivery, maintenance) - Instructional setting - Convenience - Time - Facilities - Availability - Maintenance - Support - Knowledge - Data

Table 4.1 Factors that influence the choice of Instructional Methods and Training Media

The main difference in the factors that influence choice of method and choice of media (Table 4.1) is that one of the factors upon which the decision of media selection relies is method while, when it comes to decision about method, that relies on available media.

As shown in Fig. 4.13 the relationship between media and method is not unidirectional. Media can support the instructional methodology but also can influence the development of the instructional methodology. This relationship imposes a rethink of the strategy adopted towards media selection. This new proposed strategy is expressed in Figure 4.15.

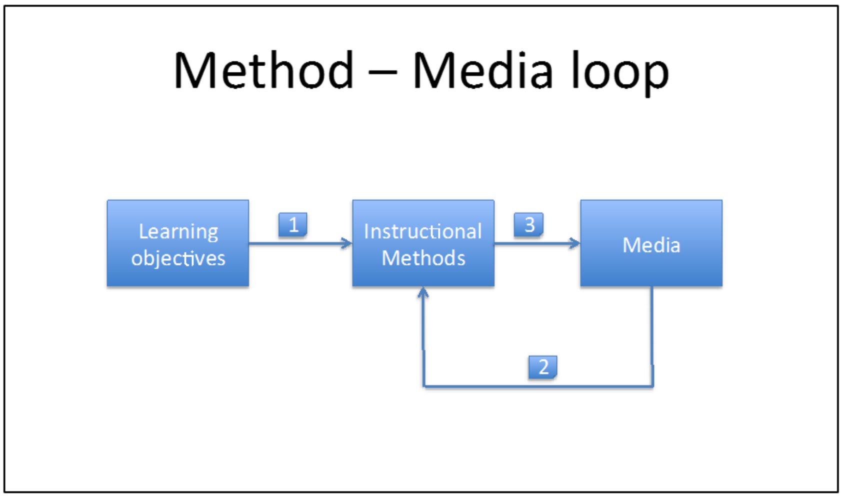

Fig. 4.15 Proposed strategy towards Training Media Selection

The strategy presented in Fig. 4.15 is based on the assumption that media does impact the transmission of information to learner and therefore will generate a change in method. As a result, when developing or choosing the instructional methods to facilitate learning, instructors should perhaps not develop or choose method based only on learning objectives (and audience) but also based on the capabilities of available media. The recommendation is that this strategy should be implemented in the following way:

1 = Use the common factors (audience, objectives) to identify, develop or select instructional method(s)

2 =Use the cognitive properties (or capabilities) of available media to improve or implement changes to the instructional method(s) selected

3 = Use the improved method characteristics to identify the media attributes necessary to support the instructional methods, and use the selected media attributes to identify and select the media or mixes of media that will possess those attributes.

It has to be mentioned that the proposed strategy does not take into account the selection of media from a cost-benefit point of view but purely from a cognitive efficiency and effectiveness stand.

4.2.3 A unified framework for selection of Instructional Process

A parallel analysis of the principles, events and categories of methods found in the literature (discussed in the Literature Review chapter) was performed. The analysis was based on concept similarities. What resulted is a collection of six main, distinct events that characterise the instructional methodology. These are presented in Table 4.2.

Architecture of Memory (1968)	**Gagne (1977)**	**Sugrue and Clark (2000)**	**Salas et al. (2001)**	**Analysis (Grouping based on similarity)**
	2. Inform Learners of objectives 4. Present the content	2. Provide information related to the task	1. Presentation of relevant information or concepts to be learned	1. Provide info
1. Attention	1. Gain attention 5. Provide "learning guidance"	1. Elaborate on the goal of the task and its demands	2. Demonstrate the KSAs to be learned	2. Direct attention
2. Rehearsal	3. Stimulate recall of prior learning 6. Elicit performance (practice)	3. Provide practice tasks and contexts	3. Create opportunities for trainee to practice	3. Provide practice
		4. Monitor trainee performance		4. Monitor
	8. Assess performance	5. Diagnose sources of error in performance		5. Assess / Diagnose / Evaluate
	7. Provide feedback 9. Enhance retention and transfer to the job	6. Adapt goal elaboration, information and practice task	4. Provide feedback to the trainees during and after practice	6. Provide feedback

Table 4.2 Comparison of various processes of selection of Instructional Methodology

Based on the results of the analysis, an instructional process flow diagram was developed. The diagram can serve as a guide for instructors and training designer to capture requirements for training. The diagram is presented in figure 4.16.

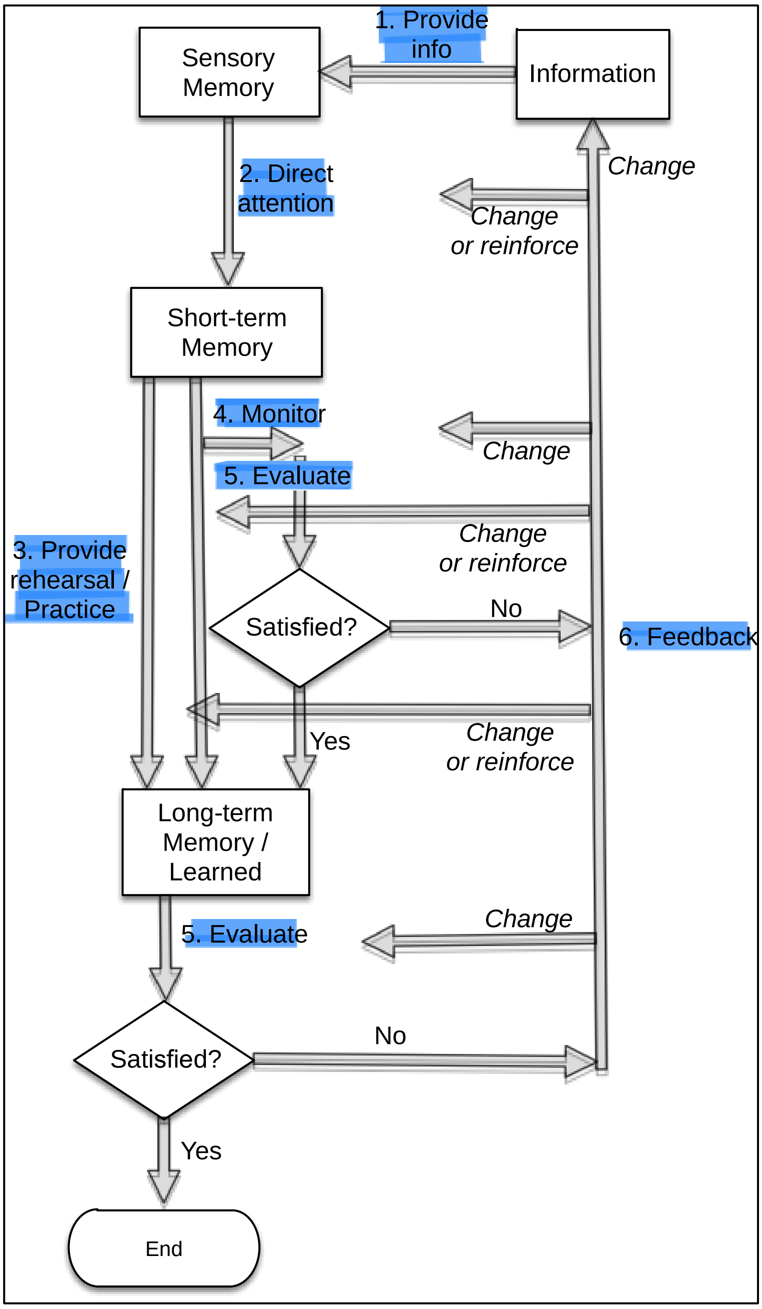

Figure 4.16 Instructional processes – unified Selection Framework

What Fig. 4.16 shows is that there are six main and distinct events that an instructional method can be built upon. Not all events are sequential, nor do they have to happen during a training session.

For each event selected the methods' designers have to take into consideration learning methods, styles and strategy to be implemented. Furthermore, the six instructional events must be considered in turn for each individual learning objective.

The benefit of using this model for training construction is that it offers a single framework to work with when designing and developing the instructional methodology and encourages thinking regarding timing and sequencing of instructional events, which is especially useful for designing the training at a technical level.

The developed models and framework presented in this section (4.17) are directed towards training analysts that can use them to support the decision-making process of method and media selection for training, in the analytic phase of training construction. Their role is visually put into context in Figure 4.17, illustrating how they relate to stakeholders and what stages of the training development lifecycle they are applicable to. The training development lifecycle shown is based on DSAT process (MOD 2008) (Full DSAT process is shown in Figure 1.3)

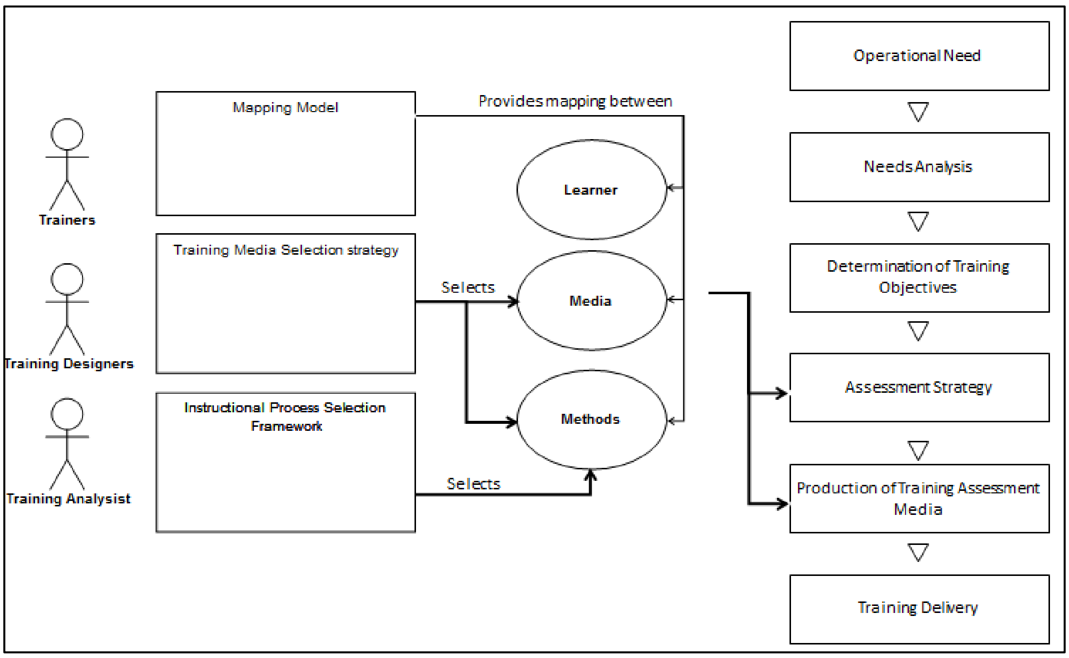

Figure 4.17 Illustration of the developed models and framework in the context of stakeholders and the training development lifecycle

Although this research is exclusively focused on aircrew training, many of the concepts discussed and proposed in this section are also applicable to analogous issues associated with media technologies used for the wider training needs. As such, it raises the question if there is a need to develop not only a common language but also a standard of interaction.

4.3 Trainee Contextual Proficiency Profile (TCPP)

This section of the chapter describes how Hierarchical Task Analysis (HTA) and the context, both derived from the operational scenario can be used to perform a trainee taylored gap analysis. The aim is that, through this technique, the decision-makers can have a clearer picture of what the competency level of the trainees is before finalising the design of the training exercise. These results could support the decision-makers at making more informed decisions regarding the construction of a training exercise.

Previous research done on competency based training such as on developing the MEC framework, discussed in the Literature Review Chapter, provides a good basis of designing and developing training/training exercises tailored on the operational and individual needs (Colegrove and Bennett, 2006) however, the high level of breakdown and categorisation does not offer in detail any indication about the level of proficiency that one student might already have. For example “intercepts and targets factors group” does not offer possibility of judging about how well a pilot knows how to do that. However, by knowing in which other circumstances (used equipment, environmental conditions, etc.) the trainee has practised some of the tasks included in the training exercise will help to understand better the competence of the trainee and thus better design the training exercise.

As such, this research proposes a novel approach to capture the trainee’s previous experiences in relation with the operational context needs that he or she is training for (hence the 3rd research question: How can the differences between trainees’ experiences be identified?). The approach is intended to support the decision-makers in showing specific areas where trainees have (or have not) a lack of skills or knowledge, at what level do they possess those skills and in what contextual conditions they acquired those skills, compared to the operational context for which the training is required. The assumption here is that all training is constructed in such a way to prepare trainees to be proficient in the operational environment.

The TCPP Approach

For constructing tailored training it is important to capture the contextual specific skills that the trainees have acquired from previous experiences and their level of proficiency (De Coy et al., 2007). The analysis done through the proposed approach therefore is intended to highlight areas where trainees lack skill and knowledge necessary for operational environment.

The approach differs from others through the fact that it offers a comprehensive overview and allows insight into the operational context specific skills and knowledge that a trainee might possess or not. This will enhance the training construction process for tailored training by showing the gap in skills and knowledge that a trainee might have in strict connection with the context of the training exercise (constructed to prepare the trainee to operate in the operational environment) for which he or she is being prepared.

The TCPP tool

To demonstrate the TCPP, data extracted from Pike and Huddleston (2011) *"Training Needs Analysis for Team and Collective Training"* Report was used. Pike and Huddlestone research was chosen because it is publicly available and offers sufficient data to exemplify the proposed method, its scope is within the TNA and it addresses team and collective training, which widened the scope and applicability of the proposed approach from individual training types of exercises to team types of exercises.

The Pike and Huddleston (2011) research report was devised to provide guidance on the TNA process conducted for Queen Elizabeth (QE) Class Aircraft Carriers. The guidance provided in the document was intended to extend and amplify the extant guidance on TNA provided by the JSP822.

Pike and Huddlestone developed a TNA methodology to be applied for team and collective training, TCTNA, which is devised around a TNA Triangle Model that has the following components: Constraints Analysis, Team/Collective Training Analysis, Training Overlay Analysis, Training Environment Analysis and Training Option(s) Selection. Some of their key deliverables were the Operational/Business Task Analysis (OTA), the Training Gap Analysis and the Training Options Analysis. (Pike and Huddlestone, 2011)

To illustrate various elements of TCTNA method, the researchers used a Tornado F3 Pairs training exercise example. The example was used as a case study to run through the three analysis phases. The scenario of the training exercise is based on *"the requirement to provide enhanced training in pairs tactics for Tornado F3 pilots and Weapons Systems Operators (WSOs) in training"* (Pike and Huddlestone, 2011, p.40). The scenario is: a pair of fighters patrolling an airspace area searching for bandit fighters or bombers. The aim of the pair is to destroy the bandits Beyond Visual Range (BVR). (Pike and Huddlestone, 2011). The full scenario is described in Appendix 8.

The specific information used from the Pike and Huddleston study was the Hierarchical Task Analysis and the Role Matrix. The way the data was used is going to be explained in the following section. The data from Pike and Huddlestne report was used as input data for TCPP tool.

The process within the TCPP tool

A process is a sequence of logical tasks and subsequent steps that an analyst has to do in order to achieve a particular objective. The process defines "what" has to be done and the structure provides support to various decision-making needs. (Martin, 1997).

To map the process followed by the TCPP tool, a sequence diagram was used, which is presented in Figure 4.18. The rational for using this type of diagram is that it facilitates incorporation of the process within an eventual computer-based tool, such as a DSS (i.e. sequence diagrams are part of UML (Unified Modelling Language) that is utilised by software developers to design and develop software based systems) (Rumbaugh et al., 2004).

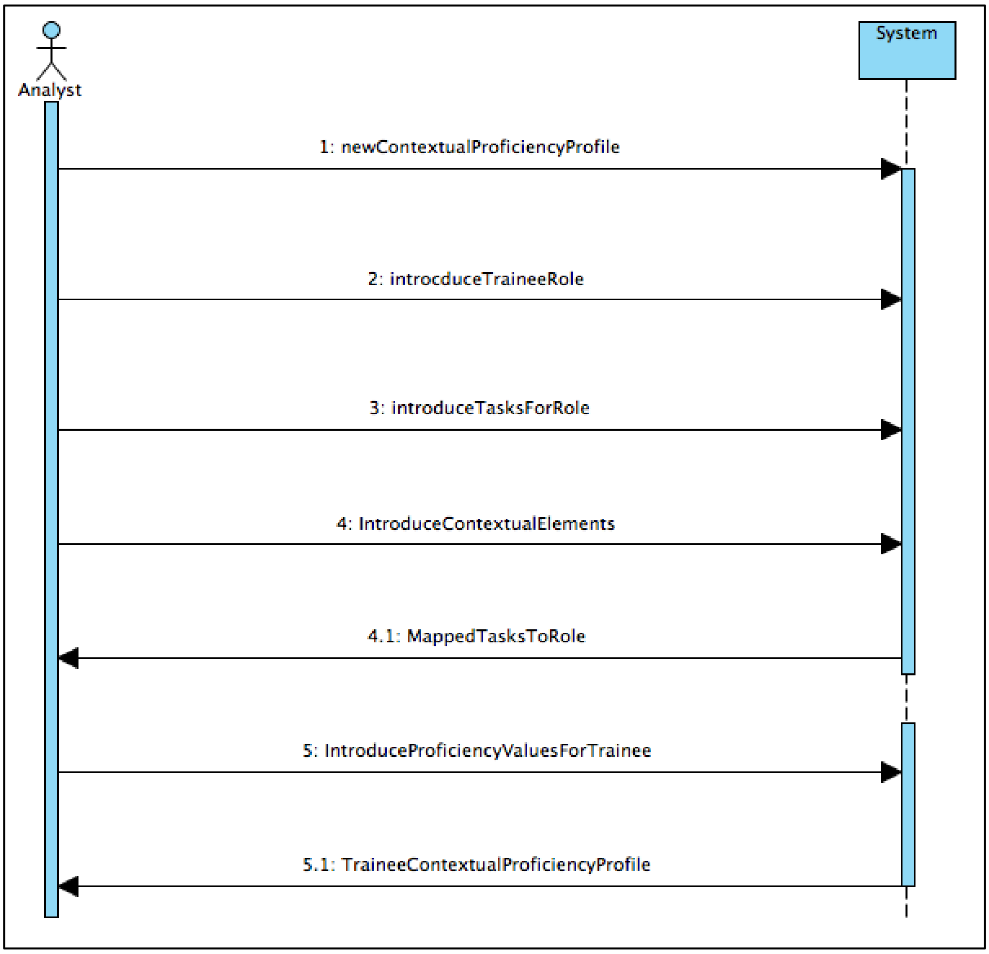

Fig. 4.18 TCPP Tool Process structure (steps)

The steps in the process depicted in Fig. 4.18 represent the actions that the user has to do for the system (the tool) to deliver the output. The arrows that go from “the analyst” to the “system” are actions for the user, and the arrows that go from the “system” to the “analyst” are actions that the system will perform.

As it can be seen in Fig. 4.18, at the beginning of the process (newContextualProficiencyProfile), the analyst has to define the role that the trainee will have in the training exercise. The role is established based on the scenario of the training exercise.

Using the scenario as a starting point, the analyst can identify the tasks associated with the specific roles. These are introduced as well in the analysis (step 3). The need to define roles and task associated with roles arises only when there are exercises where more than one student is trained. In the case that the training exercise is designed for just one trainee, this step in the process (step 2) is ignored and the subsequent step (3) will only regard the introduction of tasks. Furthermore, using the training exercise scenario, the analyst will introduce the contextual elements that are specific to the scenario (step 4). These can vary from exercise to exercise depending on the focus of the training.

Once the roles, associated tasks and contextual elements are defined and introduced, a table can be generated (step 3.1 in Fig. 4.18) where the tasks that each trainee has to do are mapped against the training exercise contextual elements. In the present example the table was compiled in Excel. However, any other tool that can provide a similar output can be used. It is advised, though, that the tool used should allow export of the data for/to generate Microsoft Excel surface like charts.

The analyst will further fill the table with values from 1 to 4 (Fig. 4.19). The values are indicative of the level of proficiency that the trainee will have for each task across each training exercise contextual element.

Task ##### Context	Platform	Env.	Terrain	Population	Weather	Forces	R&R
1.1	1	1	1	1	1	1	1
1.2	4	3	1	1	2	1	1
1.2.2	1	2	1	1	2	1	1
1.3	1	2	1	1	2	1	1
1.3.1	1	1	1	1	2	1	1
1.3.2	1	2	1	1	2	1	1
1.4	4	3	1	1	2	1	1
1.4.3	2	3	1	1	2	1	1
1.4.3.2	3	2	1	1	2	1	1
1.4.3.4	3	3	1	1	2	1	1
1.4.3.5	2	2	1	1	2	1	1
1.4.3.6	2	2	1	1	2	1	1
1.5	1	1	1	1	1	1	1
1.5.2	1	1	1	1	1	1	1

Fig. 4.19 Example of Task-Context Matrix
(the 1 to 4 scale indicates the level of experience, where
1= trainee has previous experience of doing the task under similar conditions, and
4 = trainee has no previous experience of doing the task)

For example, a value of 1 is indicative that the pilot has previous experience of doing that particular task in the same contextual instance as the one in the training exercise that he or she will undergo, while a value of 4 is going to be allocated when the trainee has no previous experience of doing the task in a similar contextual instance as the one in the training exercise. The method of allocating the values will be further explained and exemplified in the next section.

The output of this analysis will be a carpet plot, such as the one in Figure 4.20, where the level of proficiency for each trainee can be ~~easily~~ visualised and can serve as input in subsequent training design analyses. In Fig. 4.20 each task where the trainee lacks skills and knowledge can be seen. This information can help a training analyst to tailor the training exercise for specific individual needs.

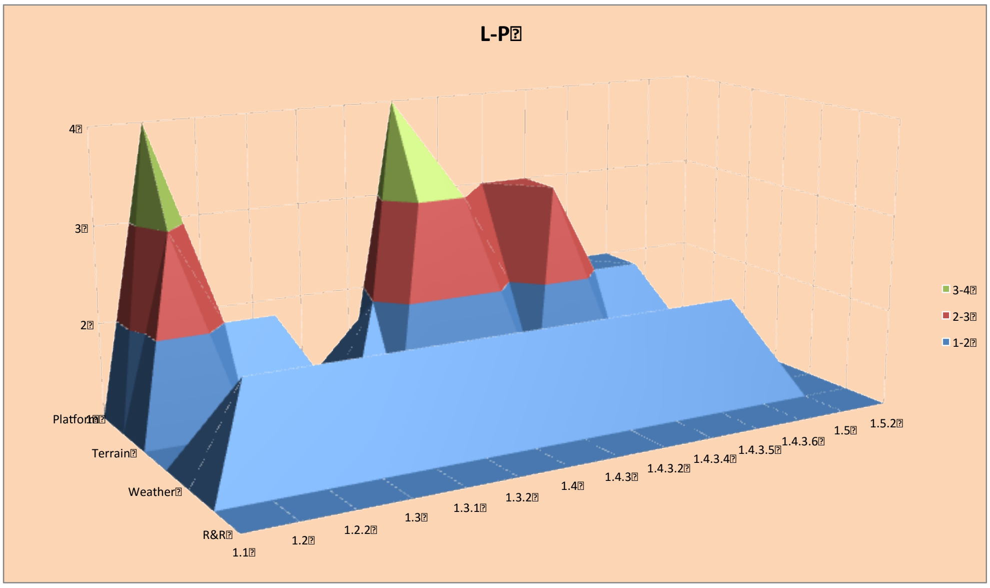

Figure 4.20 Example of graphical output of TCPP

Using TCPP – an example

Methods enhance the structure of a process and specify "how" a task from a process should be performed (Martin, 1997). Usually methods imply various types of analyses and specifications of tools with the help of which those analyses can be performed.

This section will present the analyses comprised in the present proposed approach to determine the trainee contextual proficiency profile. Furthermore, examples of tools that can be used in those analyses will be given. These will be highlighted with the help of the data from the Pike and Huddlestone research study.

The first steps (2 and 3 in Fig. 4.18) in the TCPP require identification of tasks and roles of each trainee (if there are more than one). This can be done by consulting a Hierarchical Task Analysis and a role matrix table or any other means through which tasks and role specifications are defined.

Hierarchical task analysis (HTA) is a process through which there are established tasks and subtasks that must be performed in order to meet a goal (Kirwan and Ainsworth, 1992, Shepherd, 2001). In the present case study, the tasks and subtasks have to be performed by human operators: the trainees. Through HTA the main goal is broken down into tasks and their subsequent sub-tasks in a hierarchical fashion (Kirwan and Ainsworth, 1992). In the example that was chosen, the goal is to destroy bandit fighters beyond visual range.

The main goal of the HTA is to provide a rigorous method of examining practical tasks (Shepherd, 2001) and this is the reason why HTA was chosen to be incorporated into the present type of analysis. That is because the present type of analysis is directed towards practical types of training.

The HTA is stopped when the Subject Matter Expert (SME) is satisfied with the level of breakdown. The level of breakdown and the reason for stopping may vary from situation to situation (Kirwan and Ainsworth, 1992). Because of this reason and to demonstrate the additional value of the TCPP approach, the HTA produced by Pike and Huddlestone (Fig. 4.21) was used. The breakdown does not include all the tasks and sub-tasks, but it provides sufficient information to illustrate the method. The HTA as found in Pike and Huddlestone (2011) research can be found in Appendix 9.

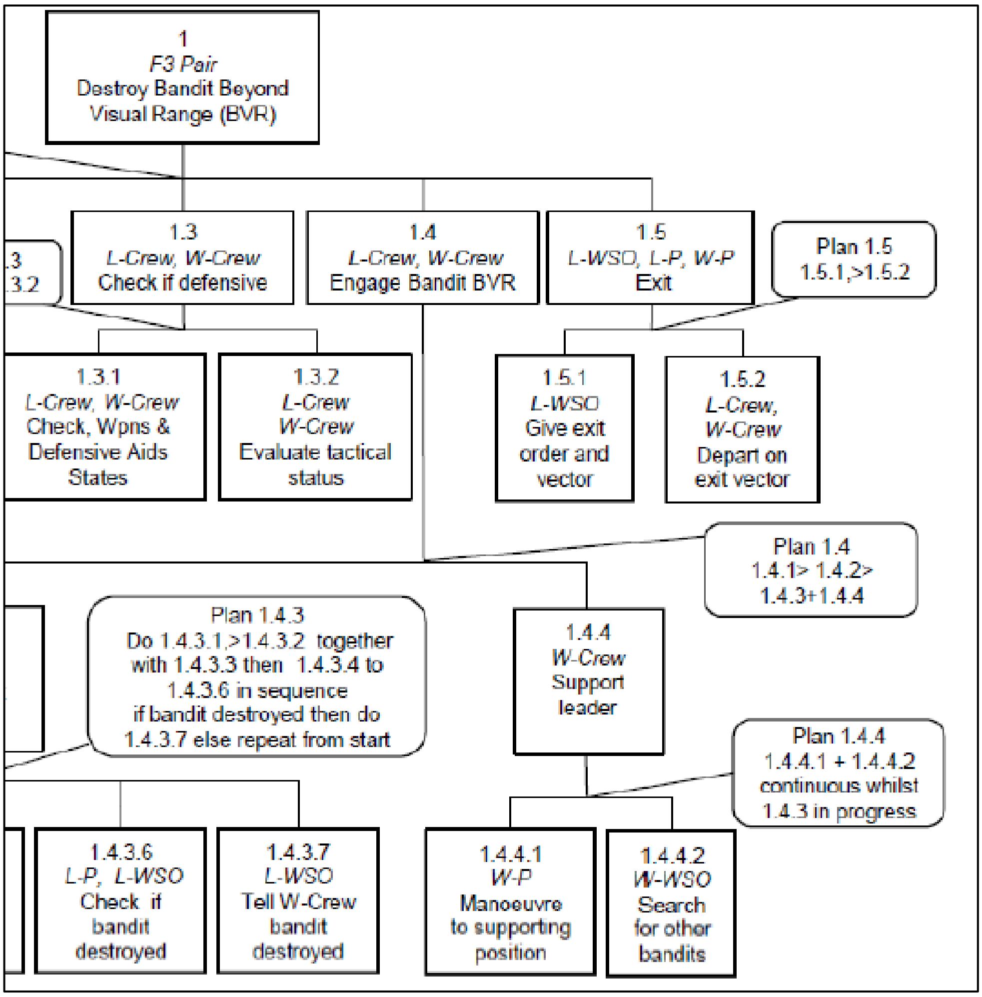

Fig. 4.21 Snapshot from Pike and Huddlestone HTA example (2011)

After the HTA analysis is completed and the task and sub-tasks identified (step 2 in the Fig. 4.18), the tasks and subtasks are allocated to individual trainees, based on the role that they need to perform in training (step 3 in Fig. 4.18). In the present example, and as can be seen from Fig. 4.21, some of the tasks are required to be done by one or more trainees. To identify which tasks and sub-task are associated with specific roles, a Task and Role Matrix analysis can be performed. However, this is not necessary for training exercises that involve a single trainee, nor are they exclusive for cases where more than one trainee is involved. One can use any method one wishes as long as the output will be identification of roles and their associated tasks and sub-tasks.

A snapshot form Pike and Huddlestone task and role matrix example that was used within the current research is presented in Fig. 4.22. In Appendix 10 can be found a larger version of the task-role matrix analysis as is found in the Pike and Huddlestone (2011) report.

Task List	Roles Participating			
	Lead-Crew		Wingman-Crew	
	L-P	L-WSO	W-P	W-WSO
1.1 Check for Bingo Fuel	X	X	X	X
1.2 Detect Bandit BVR	X	X	X	X
1.2.1 Allocate radar search bands		X		
1.2.2 Manoeuvre formation	X	X	X	
1.2.3 Liaise with Fighter Controller		X		X
1.2.4 Locate bandit		X		X
1.2.5 Meld radar		X		X

Fig. 4.22 Snapshot from Pike and Huddlestone Task and Role Matrix Example (2011)

Once the trainees' roles and their associated tasks and sub-tasks have been identified, these can be mapped against the contextual specific training exercise elements. The result is a table that will further need to be populated by the analyst with proficiency values. This constitute step 5 (Fig. 4.18) of the proposed method.

The proficiency values are determined by looking at the contextual conditions in which a trainee has (if at all) previously done that specific task. The more similar the conditions in which the trainee has previously done the task with the current training exercise, the higher the level of proficiency the student has will be assigned.

In this example, proficiency was devised in four levels: same, similar, dissimilar and none. This is an ordinal scale where "same" has an allocated value of "1" while "none" a value of "4". The analyst will judge first if the trainee has previously done the task in the current exercise contextual condition. If the answer is "no" the judgment is stopped and value "4" is allocated. If the answer is "yes", the analyst will judge further, if the trainee has done the task in the same, similar or dissimilar condition to the one in the current training exercise and will allocate a corresponding value. This decisional process is depicted in Fig. 4.23.

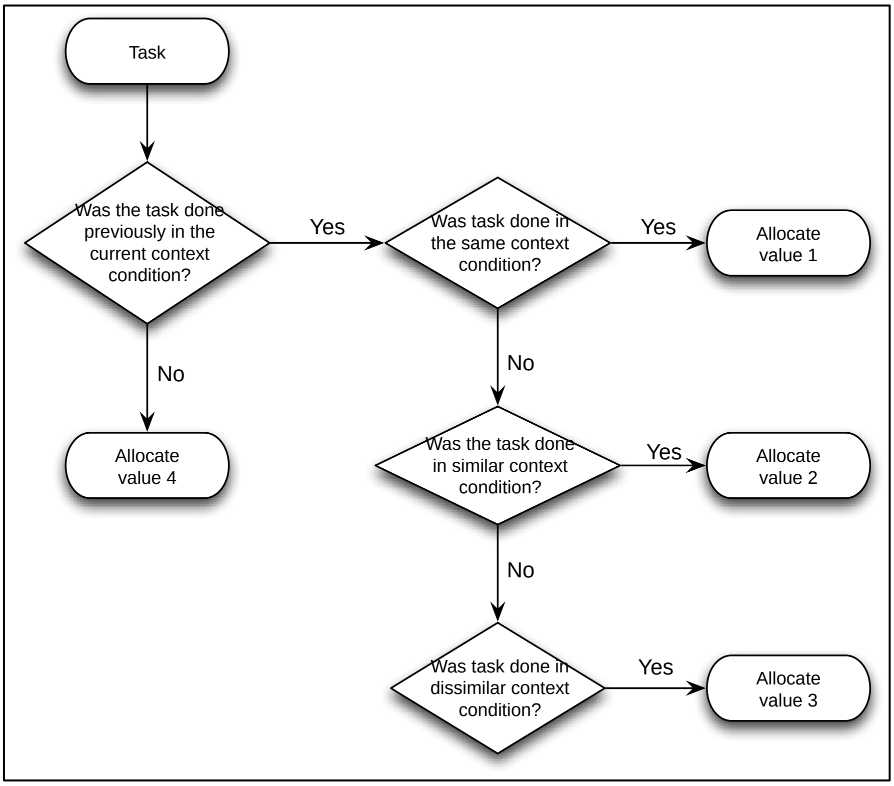

Fig. 4.23 Proficiency values - allocation process

For instance, we know from the training exercise scenario example that the trainees will have to operate a Tornado F3. As a guideline, for example, if we take the task *1.2.2 Manoeuvre formation* (Fig. 4.21) and the contextual condition element *Platform,* then, when the analyst will ask the questions (Fig. 4.23), *same* will mean Tornado F3, *similar* will mean platform with similar capabilities and *dissimilar* will mean platform with different capabilities.

This process is run until all the tasks have been judged against all the contextual conditions elements and the Task-Context Matrix (Fig. 4.22) has been completed. Throughout the process, the question remains the same but the task and the contextual element under consideration will change.

The output of this analysis (Fig. 4.20) will show decision-makers what skills the trainee has and at what level the trainee has mastered that skill, so a judgement can be made regarding the design of the training exercise that the trainee will undertake. The peaks show where the largest gaps in the skills are while the floor shows what skills a trainee has the highest level of proficiency in. The distribution of task and elements and visualisation mode of the chart can be easily changed to suit the decision-maker preference. By plotting the data into a surface like chart, fast and easy visualisation of the results is facilitated. The peaks show where the largest gaps in skills are, given the training scenario. Also, the chart shows the status of the other skills.

The TCPP analysis output is intended to support primarily the decisions made by the analysis regarding complexity and layout of the training system. This information then can be used to refine the TNA and/or used as input in subsequent stages of training design and development.

The Trainees Contextual Proficiency Profile is visually put into context in Figure 4.24, illustrating the stakeholders, the input and outputs of and where in the training lifecycle it can be applied. The training development lifecycle shown is based on DSAT process (MOD 2008) (Full DSAT process is shown in Figure 1.3).

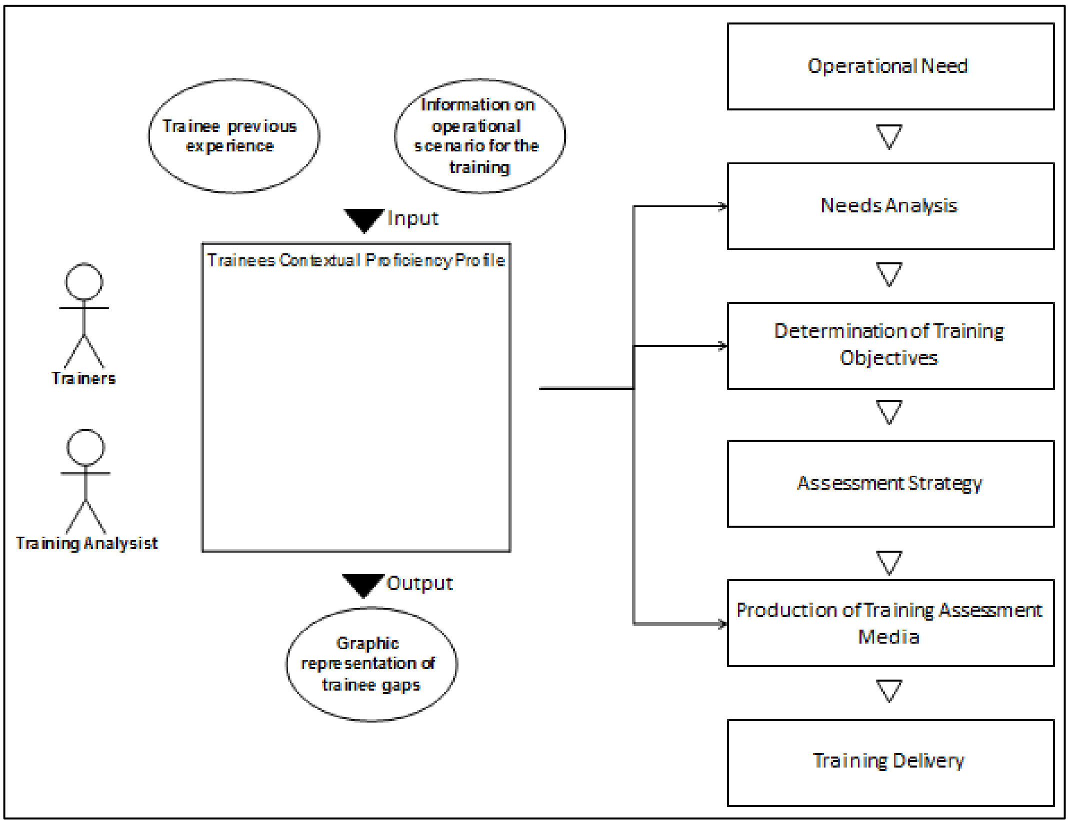

Fig. 4.24 The TCPP illustrated in the context of stakeholders, input/outputs and the training development lifecycle.

4.4 TNA output Analysis (ToA) concept-tool

The first step in any design and development of training is to analyse the training needs (TNA). As such, a lot of attention and research is directed towards this phase of training construction, i.e. in capturing and expressing the training needs. The training needs are important because it forms the basis of the training requirements on which the training programme/exercises will be developed.

There are rules, guidance and standards on how to write requirements as well as tools used to capture, elicit, analyse and manage requirements. However, the process is highly time and resource consuming, specialised training is required, and all this does not prevent interpretation-errors, especially when the requirements are communicated or transferred across domains. For example, performance, implementation and/or system requirements for the training needs analyst might not be the same type of requirements for an engineer. The customer (BAE Systems) as well as other interviewed SMEs identified that the transition of the TNA outputs to training design requirements is problematic (Subsection 1.3.3 Industry needs).

The information although valid, when it is transferred from the analysis phase to the design and development phase, has to go each time through a transformation process. This is illustrated in Figure 4.25.

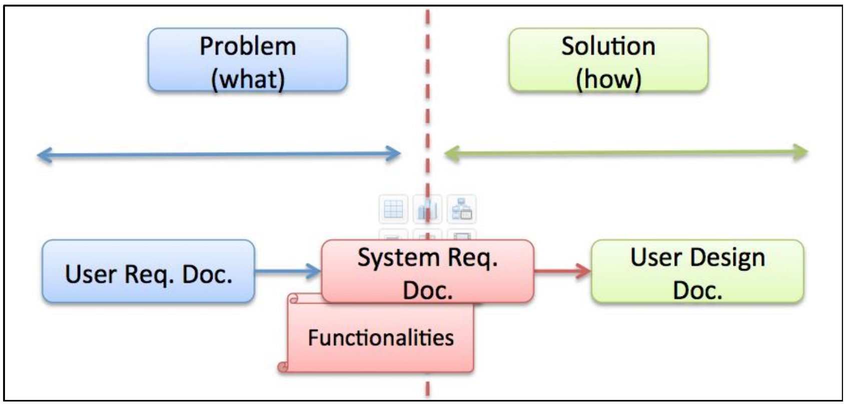

Fig. 4.25 Training needs to training requirements

This information transformation process usually is time and resource consuming and prone to interpretation errors as it deals with text/language (Gotel and Finkelstein, 1994). As such, research efforts were directed towards developing a TNA output analysis method to minimise the time and resource consumption and to reduce interpretation errors.

The ToA method was developed based on the SE design principles and applies them within the construction of training process. This method was created to support and encourage decision-makers to first examine the goals of the training, then the functions of the training needed to be achieved then to identify the necessary components to deliver those functions and integrate them in a training system environment that will deliver the required training.

The TNA output Analysis (ToA) purpose is to capture and process the information resulting from the TNA in such a way that the TNA information can be effectively transferred to subsequent stages in the process of constructing the training environment.

Within the training construction process, the analysts and engineers' goal is to realise an effective and efficient system for the training to be delivered. According to Systems Engineering (SE) design principles, in order to create a system it is advised that first, the purpose or goal of the system is investigated. This phase corresponds to what is known as gathering and analysing the system requirements. Through the process of requirements analysis, the properties and characteristics of the system are highlighted, which in turn will provide the systems functionalities. The functionalities will further represent the system design requirements based on which, the engineers can identify and select/or construct the system components through which the functionalities of the system will be achieved; (Fig. 4.25).

The SE design process is presented in the upper part of Figure 4.26. This process is a SE specific methodology known as the "V model" that systems engineers employ to design and develop systems. It starts with specification of System Requirements and finishes with the System Development while in the lower part of the Fig. 4.26 the training construction process is shown. As presented in Fig. 4.26, the ToA role is to capture the training requirements and to make the transition of this information from the analysis to the design domain. In Figure 4.26 the arrows represent the flow of information.

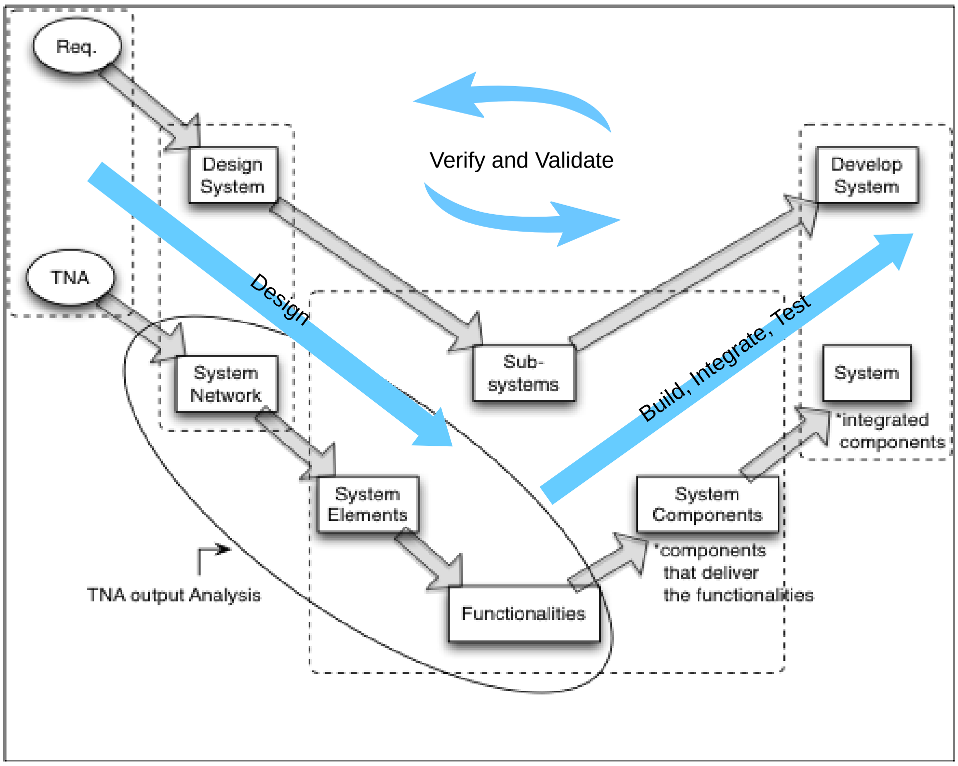

Fig. 4.26 The role and place of ToA within the training construction process

As depicted in Fig. 4.26, the ToA covers three phases of training construction, the system design through the depiction of the system requirements network and the system elements and functionalities of those system elements. The realisation of the system requirements network is based on TNA information and it serves as support for identifying the components of the training environment.

The SE design approach differs from the more traditional, solutioneering approach where solutions are delivered fast and usually the decision-makers arrive at versions of the solutions that they used in the past. This is not necessarily wrong, however, this approach can hinder the possibility of choosing new developed systems that might accomplish some functions better and in a more efficient way.

The ToA was designed to break down the TNA information to be inspected and analysed by decision-makers (analysts and engineers). What ToA offers is a holistic picture of the system requirements as well as an in-depth view of the components of the requirements. The requirements components can then be examine based on their associated attributes, represented by links that a component could form with other components of the requirements network.

The ToA method was designed to be used as an inspection tool where the decision-maker can analyse the training requirements components and their attributes. The attributes can then be used to specify the training environment functionalities that the training media systems need to satisfy.

The ToA approach

A specific method was designed to input the data (e.g. the TNA information or training requirements) in ToA. The rules for the user to follow when inputting data are presented in Figure 4.27). The rules of introducing the data were developed based on SE principles of writing requirements (Hooks, 1994) and English sentence structure. When the requirements are introduced in ToA, they are decomposed in four types of elements (or components): subject, action, link and quality.

Rules

* Introduce one sentence at a time.
* Any sentence must contain two subjects* and either an action*, a link* or a quality*.
* **Do not** introduce the same type of word one after the other (e.g. subject *and* subject).
* Direction of sentence flow is from left to right (e.g. *Something does something*; **NOT**: *Something is done by something*).
* Start new sentence whenever there is a coordinated conjunction (e.g. *and*; *or*).
* Generate new sentence as often as feels necessary.

* **subject** = any word or combination of words that represents a subject of interest (e.g. *missiles*; *guided_missiles*)
* **action** = most verbs except verb "*to be*" and variation of it
* **link** = all words and combination of words (usually in combination with a verb) that show affiliation, ownership, membership; most times contains some form of verb "*to be*" it answers the question "*What?*"
* **quality** = a quality of an action, subject, or link it answers the question "*how?*"

Fig. 4.27 The rules needed to be followed to input data in the ToA

The ToA tool uses as input any type of information resulting from any type of TNA. Based on this information the ToA will produce a text based as well as a graphical representation of all training requirements, i.e. a network of requirements that shows how various requirements components are connected between them. An example of a snapshot from the ToA tool, which illustrates a network of training requirements, is presented in Figure 4.28. To illustrate the concept, for the graphic output (the requirements network) an existing open-source application Cytoscape was used. The

Cytoscape environment was selected because it is dynamic and allows inspection of each node and its connections as well as display of the network in various forms.

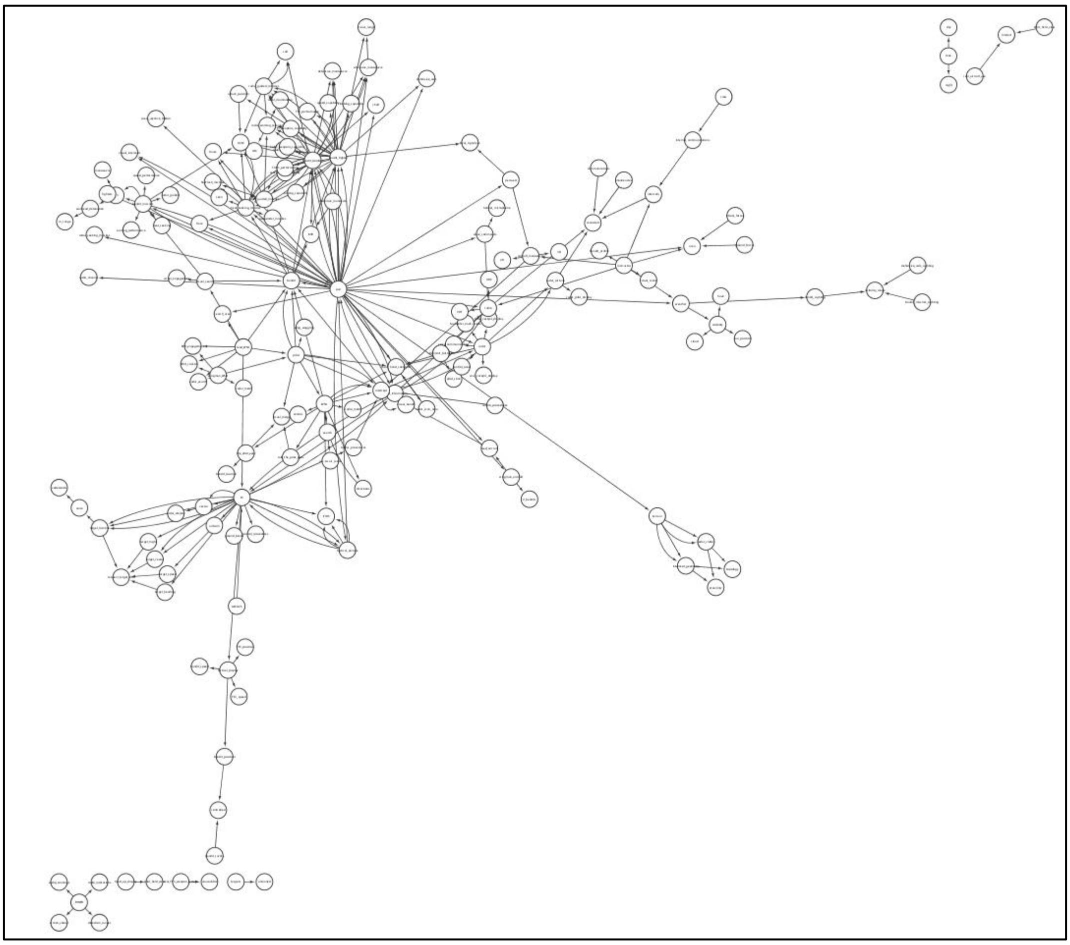

Fig. 4.28 Example of how a network of requirements could look like –snapshot

In the requirements network (e.g. in Figure 4.28), the requirements components correspond to the network nodes (the spheres in Fig. 4.28), while the arrows between the nodes corresponded to the links between the elements of a requirement. The arrows also show the directionality of the information so that the decision-maker can trace where a component comes from. The network of links that is formed between a node and its immediate neighbours represent the totality of attributes of that element while an attribute of an element is represented by one link with only one immediate neighbour.

The network-like view of training requirements offers the decision-makers a holistic view of the requirements while the networks of links between a requirement element and its neighbours offers an in-depth view of requirements at an element level. Although the network looks busy and difficult to grasp in its entirety, it can reveal what elements the requirements are concentrated on (clusters of arrows) as well as if there are unconnected or isolated elements. Furthermore, the attributes of the individual elements can be examined further by selecting individual nodes and their neighbours if required. This information can be useful when constructing the training at it allows in-depth examination of training prior to design and development.

Using this method as a way to capture and investigate the training requirements could save organisations considerable time and effort. The user does not need intensive specialised training on how to input the information though it is recommended that the person who is introducing them be a training needs analysts (but not necessarily a systems requirements specialist). Using a tool like this may reduce the amount of time spent on writing, documenting and transferring requirements. Furthermore, it could offers a common platform for discussion and analysis of requirements between the training analysts and training design engineers.

The TNA output Assessment (ToA) is visually put into context in Figure 4.29, illustrating the stakeholders, the input and outputs of the tool and where in the training lifecycle it can be applied. The training development lifecycle shown is based on DSAT process (MOD 2008) (Full DSAT process is shown in Figure 1.3).

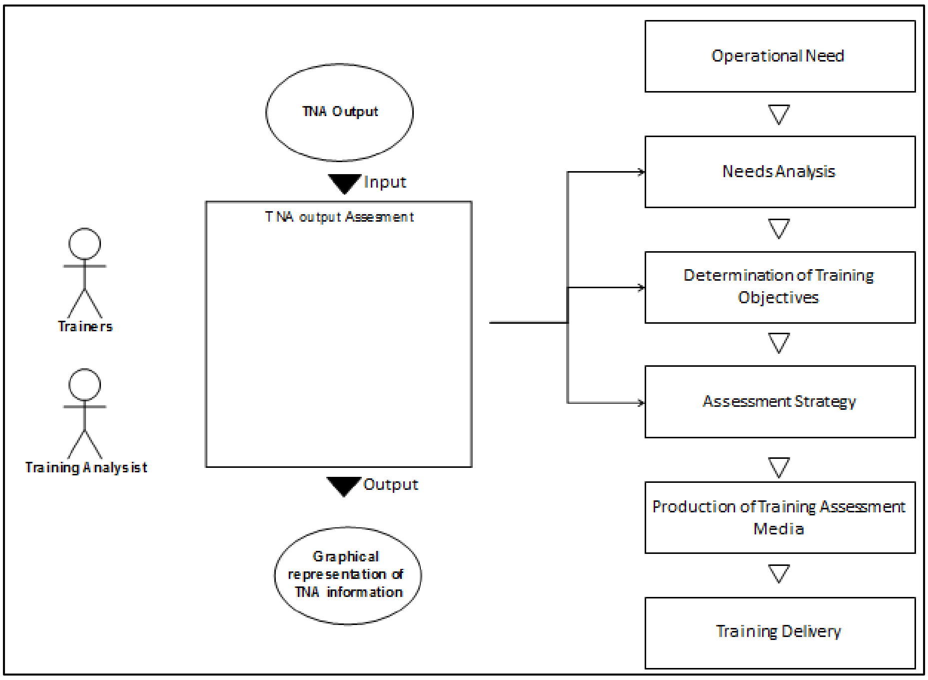

Fig. 4.29 The TNA output Assessment (ToA) illustrated in the context of stakeholders, input/outputs and the training development lifecycle.

4.5 Chapter Summary

This chapter has described the research conducted to address the research questions set at the beginning of this thesis (Chapter 1 Introduction) and the development of solutions to support the construction of training media. Two concept-tools have been produce, the TCPP and ToA, to address issues related to identification of trainees' previous experiences and management of TNA outputs (RQ 3 and 4). Furthermore, a multidimensional classification framework has been developed to support the differentiation and definition of training media (RQ 1). To address RQ 2 models that map the relationships between media, learner and method were developed based on existing research and theory and new a new proposes for media selection has been proposed, as well a unified framework for selection of Instructional Process.

Chapter 5

Evaluation

This chapter presents the evaluation process of the research outputs discussed in chapter 4. The goal and purpose of the evaluation is discussed in section 5.1. The data used is presented in section 5.2 and the results of evaluation in section 5.3. The chapter ends with section 5.4 Discussions and Conclusions.

5.1 Goal and purpose of evaluation

The purpose of the evaluation, in Systems Engineering (SE) terms is to verify and validate a proposed system. The verification process checks if the system was built right while the validation process checks if there was built the right system (INCOSE, 2011). Within the SE approach, verification and validation is a process step that applies to all stages and throughout the entire SE process, from requirements generation to system build. The evaluation presented in this thesis concerns the evaluation of TCPP and ToA systems only at concept phase. The two systems need to be developed further for a complete SE evaluation (e.g. detailed design & built).

The rest of the research outputs: the Training Media Classification Framework, the Cognitive model of interaction between media, method and learner, the new Strategy for Training Media Selection and Framework for Selection of Instructional Process, are at a lower stage of development (theoretical phase) compared to TCPP and ToA, and therefore they could not be evaluated to the same extend. Although there was feedback from the customer (all research outputs have been presented to the customer, including this thesis) regarding these research outputs, more research is needed to further develop and evaluate these outputs.

5.2 Data used

Two data sets were used to evaluate the TCPP and ToA concept solutions:

- Data Set 1 – was extracted from the literature, more precisely from the Pike and Huddlestone (2011) research study,
- Data Set 2 – was provided by the customer (BAE Systems).

These data sets were used in two separate case studies that will be referred as Case Study 1 for the one were Data Set 1 was used and Case Study 2 for the Data Set 2.

Both sets of data are TNA analyses, however, these TNAs were performed at different stages in the process of constructing training programmes. The distinction is highly important as the characteristics of data impact the outcome and therefore the purpose of use of the methods.

The TNA provided by the customer (Data Set 2) was conducted with the scope of determining the training required for a previously identified capability gap and is concerned with analysing the training needs for a whole training syllabus while the TNA from Pike and Huddlestone study (Data Set 1) concentrates on analysing the training needs for a specific training exercise. Documented information about the two TNAs can be found in Appendix 11. The main difference between the two is that a training syllabus contains multiple and various types of training exercises. Because of this aspect, the depth of information in the two TNAs varies.

Although the TCPP and ToA are not directly concerned with the creation of TNAs, the data and the data types produced as a result of conducting these TNAs serves as input for both tools. Understanding the context from which the data is generated is of value in understanding the TCPP and ToA and their use.

There is no single data description that applies to all TNAs. For instance, the two data sets used in the evaluation do not use identical data categories. These are presented in Table 5.1.

Case Study 1	Case Study 2
Constraints Analysis • Constraints table Team/Collective Task Analysis • External Task Context Description - Generic Scenario Table - External Team Context Diagram - Interaction Table - Environmental Description Table - Environmental Task Demands Table • Internal Task Context Description - Organisational Chart - Role Definition Table - Internal Team Context Diagram - Interaction Table - System Matrix - Communications Diagram - Communications Matrix • Hierarchical Task Analysis for Team/Collective Training (HTA(TCT)) - HTA (TCT) Diagram - Task Sequence Diagram - HTA (TCT) Task Description Tables - Task Role Matrix • Teamwork Analysis - Teamwork Process Priority Table - Teamwork Interaction Table • Training Gap Analysis - Training Priorities Table • Team/Collective OPS and TO Development Training Overlay Analysis • Instructional Method Selection - Practice and Assessment Methods Table • Training Scenario Specification - Training Objective Generic Scenario Table - Environment Description Table • Instructional Task Identification - Instructor Task Table • Training Overlay Requirement Specifications - Environment Specification Table Training Environment Analysis • Training Environment Specification • Training Environment Rationalisation • Fidelity Analysis - Environment Option Description Table • Training Environment Option Identification • Training Environment Option Definition - Training Environment Option Description Table - Training Environment Option Properties Table • Training Environment Option Evaluation - Training Environment Option Comparison Table	[…] Basic Pilot – Output Task Statement • Difficulty, Importance and Frequency (DIF) Analysis • Conditions and Standards […] Basic Pilot – Training Gap Analysis • Training Gap Statements and Train/No Train Decisions • Training and Enabling Objectives • Training and Enabling Objectives Consolidated list by Phase […] Basic Pilot – Phase 2 Media Matching Analysis • Media Allocation […] Basic Pilot - Phase 3 Media Matching Analysis • Media Allocation TNA Verb List

Table 5.1 Documents from which Data Set 1 and Data Set 2 were extracted

5.3 Analysis and results

From the point of view of the user, the TCPP and ToA methods are systems that gather, process and store information. As systems, the two methods support the decision making process to construct training programmes as defined by the MoD (Figure 1.4) by providing a reference point for the training requirements and pilot proficiency levels. As such, the methods can be of use for both the training analyst as well as for the training designer.

5.3.1 Verification of TCPP

The purpose of TCPP is to establish the trainees' proficiency profiles given the specific context and the tasks that they will have to perform in an operational or training scenario. The TCPP method of analysis of trainees pilot proficiency levels identifies the trainees' specific needs and therefore can supplement (not replace) the TNA.

The TCPP analysis does not investigate the trainees' overall proficiency levels but rather shows their readiness level to perform the tasks defined within the TNA given their previous experience of performing those tasks in the operational/training context that they will face.

As a general rule, TCPP uses as input the following type of information:

- Trainees' roles
- Trainees' numbers
- Tasks to be performed
- Context specific elements (e.g. devices, rules such as Rules of Engagement, weather) – these can and do vary from exercises to exercise
- Information about trainees' past experiences that can be collected from documents such as: existing profiles, assessments, log books
- Established proficiency scale that can vary from institution to institution (these have to be established a priori)

The data considered for TCPP analysis in the two case studies is summarised in Table 5.2. The list of TNA documents from where the corresponding data was extracted can be found in Appendix 12.

TCPP input	Data Set 1	Data Set 2
Trainees roles	• Lead Pilot • Lead WSO • Wingman Pilot • Wingman WSO	• Basic Pilot
Trainees numbers	• No knowledge • *Considered one trainee for each role*	• No knowledge
Tasks to be performed	• 27 tasks in total (from 1 TO) • 14 for Lead Pilot • 21 for Lead WSO • 11 for Wingman Pilot • 13 for Wingman WSO	• 519 EOs corresponding to 268 initial tasks and
Context Specific Elements	Devices: • Tornado F3 • Enemy operating Tornado GR1 • Friendly AWACS Time of day: • Day time • Night time Geography: • Over geographical area where ground and littoral forces may be operating Communications: • JTIDS • VHF Radio • UHF Radio • Foxhunter multi-mode radar • RHWR • Intercom • Head up Display Manoeuvres: • ACM Weather: • Cloud • Haze • Sun Weapons: • SkyFlash missiles • Sidewinder missiles • Chaff • Flares	• T-21 • Conditions: A Given access to relevant information B Given appropriate facilities/equipment C On the ground D in the air E By Day F By Night G In VMC H In IMC • Standards: 1 Demonstrate the safe, accurate operation of the system or sub-system within operating limitations 2 Assess, appreciate and implement an appropriate solution within operating limitations 3 Describe the concept and operating limitations of the system, sub-system or procedure 4 Without error in accordance with instructional specification 5 Without error in accordance with published minima and/or procedures 6 To the satisfaction of the instructor 7 In accordance with SOPs and/or aircraft documentation
Information about trainees past experience	• No knowledge • *Made up for example purpose*	10 task form the initial tasks have been identified were the trainees have limited experience or limited knowledge
Proficiency scale	• No knowledge • *Made up for example purpose*	• Limited experience/knowledge • No experience/knowledge

Table 5.2 Data used for TCPP analysis

The trainee's role in the Case Study 2 was 'Basic Pilot' and because there was no information regarding the number of trainees, the TCPP analysis was done for one trainee. In Case Study 1 the data specified four roles, however, as no specification regarding the number of trainees was available, for the TCPP analysis it was considered that there are four trainees, each with a specific role.

Regarding the tasks to be performed, although in the case of both data sets used for the case studies, information was offered to satisfy the requirements for TCPP analysis, the granularity of information is very different. The tasks listed in the Data Set 1 were hierarchical subdivisions of one Training Objective (TO). As such, the level of decomposition varied between two and three; while the tasks extracted from Data Set 2 were TOs and EOs (Enabling Objectives). Therefore, the tasks used in Case Study 2 were higher order tasks than the ones used in Case Study 1.

Regarding the context specific elements, the data used in Case Study 1 offered more detailed information about the context in which the trainees had to perform the tasks than the data used in Case Study 2. Furthermore, the type of information about the context is greatly different. As can be observed in Table 5.2, the type of information extracted from the Data Set 2 is related to the type of equipment, general conditions and standards that the trainees have to satisfy/be proficient in at the end of the training syllabus, whereas the information extracted from Data Set 2 are related to tasks, equipment, environmental conditions, etc. that trainees have to be proficient in at the end of a training exercise.

The Training Gap Statement document that appertains to Data Set 2 did offer information about the trainees' past experiences and also offered information from which a proficiency scale can be derived. However, only 4% from the totality of tasks presented in Data Set 2 were found to be linked with information about trainees' previous experiences. Furthermore, the proficiency scale that could be derived could only have two levels: limited experience and knowledge; and no experience and knowledge. These levels of proficiency were also strictly related to tasks only and no information was available about the training or operational context for which the training should be constructed. Because, for a very large percentage of the tasks in Data Set 2 it was specified that the trainees had no previous experience or knowledge, it was decided that there is too little information to perform the TCPP analysis for this data set.

Regarding Case Study 1, the Data Set 1 did not offer information about trainees past experiences or proficiency scales. However, mock-up information was added to enable the TCPP analysis.

To demonstrate the functionality of TCPP a proficiency scale was devised and experiences indices added as described in Section 4.3 in Chapter 4. This mock-up information does not affect the validity of the approach as the TCPP analysis is designed to allow the use of different tasks, context elements and proficiency scales, depending upon the needs of the analyst.

To run the TCPP analysis, Microsoft Excel was used as a platform. However, any other tool that has similar capabilities can be used. This was one of the artifacts used to verify the TCPP method.

The results of the TCPP analysis, obtained on the basis of the information extracted from the Data Set 1 are shown in Figure 5.1. A larger version of the TCPP graphic output is presented in Appendix 13.

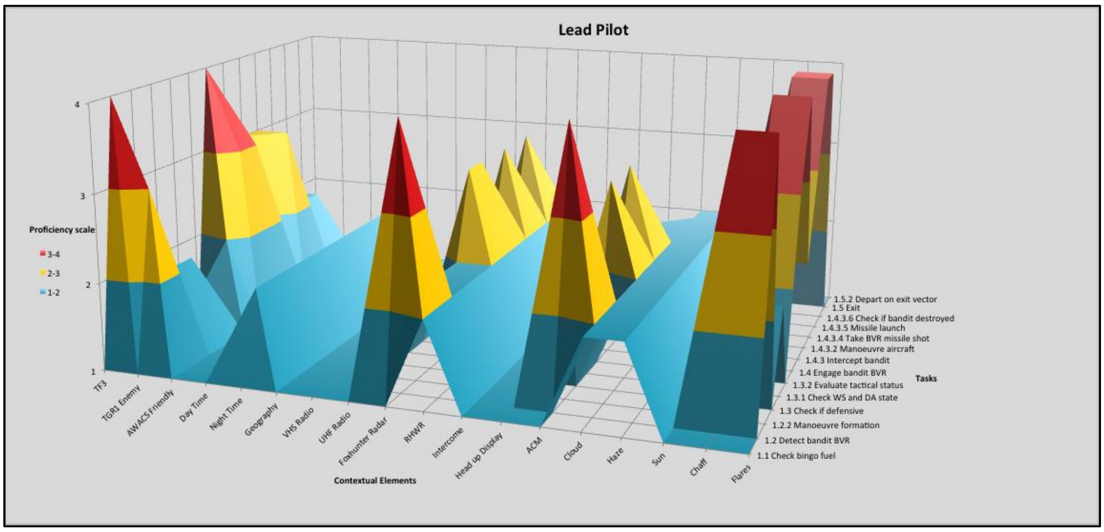

Figure 5.1 Snapshot from TCPP demo (through Excel carpet plot interface) showing the proficiency profile of a trainee for training role, Lead Pilot (Case Study 1)

On the right-hand side axis (in Fig. 6.1) there are the tasks in the exercise, on the bottom axis the training exercise contextual elements and on the vertical axis the proficiency scale. The plot shows the trainee proficiency levels for the tasks that he or she will need to perform. As the trainees will have different previous experiences, the analysis is done separately for each trainee. Figure 6.1 shows the profile for one trainee, in this case, the trainee that will have the role of Lead Pilot in the training exercise.

Although, in the above example, the TCPP analysis was done for one trainee, there is no reason why it cannot be used for a group of trainees, as long as they will be allocated the same role and have similar previous experiences (e.g. similar assessment results). For example, if there is a class of trainees of which the results can be roughly divided in upper class, middle and lower, a trainer can use the TCPP analysis for these groups to examine the readiness of the trainees to undertake the next phase of training. Then, based on the TCPP analysis the trainer can see where the training (standard/general for a whole class) needs to be modified; add more practice on some elements for specific trainees, reduce or increase complexity of the training tasks or split training sessions. The TCPP tool is designed for supporting construction of tailored training programmes and could be used on its own or integrated in other DSSs (Decision Support Systems) used to support construction of training programmes.

5.3.2 Verification of ToA

As part of developing solutions to support selection of training media to construct training programmes and in response to the requirements to facilitate the transition of the TNA outputs to subsequent stages in the training design and developing process, a method was developed to process the information resulting from TNAs. This method is referred to as TNA output Analysis (ToA).

The ToA method uses as input any type of information resulting from any type of TNA, however, the inputs have to be introduced manually based on a predefined set of rules (Figure 4.24 in Chapter 4, Section 4.4). Furthermore, it is recommended that the information is introduced in the ToA by an analyst. This is because, the TNA analysts are more experienced with dealing with requirements, so it is assumed that they will be better at spotting any mistake that might be within the data.

The ToA is designed to arrange the TNA information in a holistic and meaningful way. More precisely, the ToA will decompose the requirements into meaningful chunks and display them in a network where the links represent the connections between the chunks of information.

The ToA was designed with the purpose of being a software application. However, since it is at a conceptual stage in its development, no programming was performed yet. The challenge of evaluating the ToA in this concept-like stage was overcome by use of artifacts such as, Microsoft Excel and Cytoscape. Microsoft Excel was used to prepare data for input in Cytoscape, which is a network visualisation tool, for processing and output visualisation. As such, there are some practical differences in the way it was designed for the information to be input to the ToA and the way the data is imput for use of Cytoscape. A comparative example of input data techniques are shown in Table 5.3; in this example, information from Data Set 2 was used.

Case Study **TNA data**	**ToA** **Input-data method**	**Cytoscape** **Input-data method**
"Describe the effects of weather on T-21 flights/missions."	Pilot describes effects_of_weather on T-21_ flights/missions.	Pilot does Describe. Describe the Effects_of_weather. Effects_of_weather on T-21_flights/mission.
	ToA underlying structure	**Cytoscape underlying structure**
	Subject (1) / Action (1) / Subject (2) / Link (1) / Subject (3)	Node (1) / Interaction (1) / Node (2) Node (2) / Interaction (2) / Node (3) Node (3) / Interaction (3) / Node (4)

Table 5.3 Comparison of input data method between ToA and Cytoscape

To introduce the data in Cytoscope according to its rules, a Microsoft Excel table has been constructed based on the rules presented in Table 5.3. The Excel tables were then imported automatically in Cytoscape, which was used to create a network of requirements. These networks represent the totality of requirements for training and graphically it appears as a multitude of nodes linked together by arrows (see Figure 4.25, in Chapter 4, Section 4.4).

The links between a node and its immediate neighbours represent the totality of attributes of the node, while an attribute is represented by one link with another node.

In general, the attributes contain information such as: what an element (e.g. pilot, aircraft) has to do (describe) or be (in flight).

The same rules were applied for both data sets during the evaluation process. The output for Case Study 1 was presented in Figure 4.25. Although the image looks busy and difficult to grasp in its entirety, the system allows the user to zoom in, select a node and generate a new graph. This function allows better visualisation of individual training components and their attributes.

At the level of network, initial inspection can reveal on what specific components the training is more concentrating, as well as if there are unconnected components. This can reveal if there might be some missing information regarding the requirements, but also that some requirements are targeting a component that is related to the training but outside the immediate environment. For example, in Case Study 1, the requirements that are seen in Fig. 4.25 as not connected are related to the trainer.

To examine the attributes of individual elements the user can use two methods. One, previously mentioned, is to zoom into the network and select a node that is of interest. This is done in Cytoscape by selecting the function 'First Neighbours of Selected Nodes' then 'New Network from Selection'. The tool will produce a new graph with only the immediate links of the node of interest. Figure 5.2 (a higher resolution version can be seen in Appendix 15) shows an example of a selected node. If the user wants, there is also the possibility to select neighbours nodes of the neighbours nodes and so on, depending on the needs of the user.

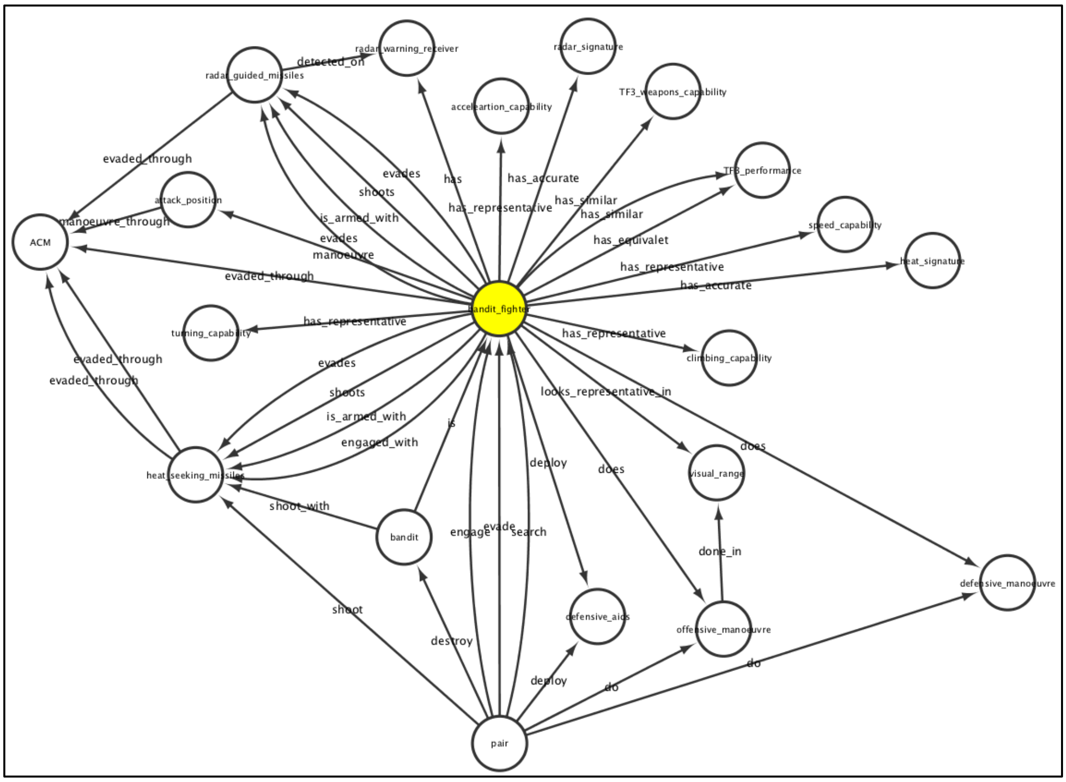

Figure 5.2 Snapshot from ToA demo (where Cytoscape interface was used) that shows a network of attributes for a single requirement component ("bandit-fighter") – Data Set 1

The other method through which the user can investigate the attributes of individual requirements' components is by selection from a list. This is a functionality designed within the ToA concept demonstrator module. Figure 5.3 presents the list-view of attributes for the same component presented in form of a graph in Figure 5.2.

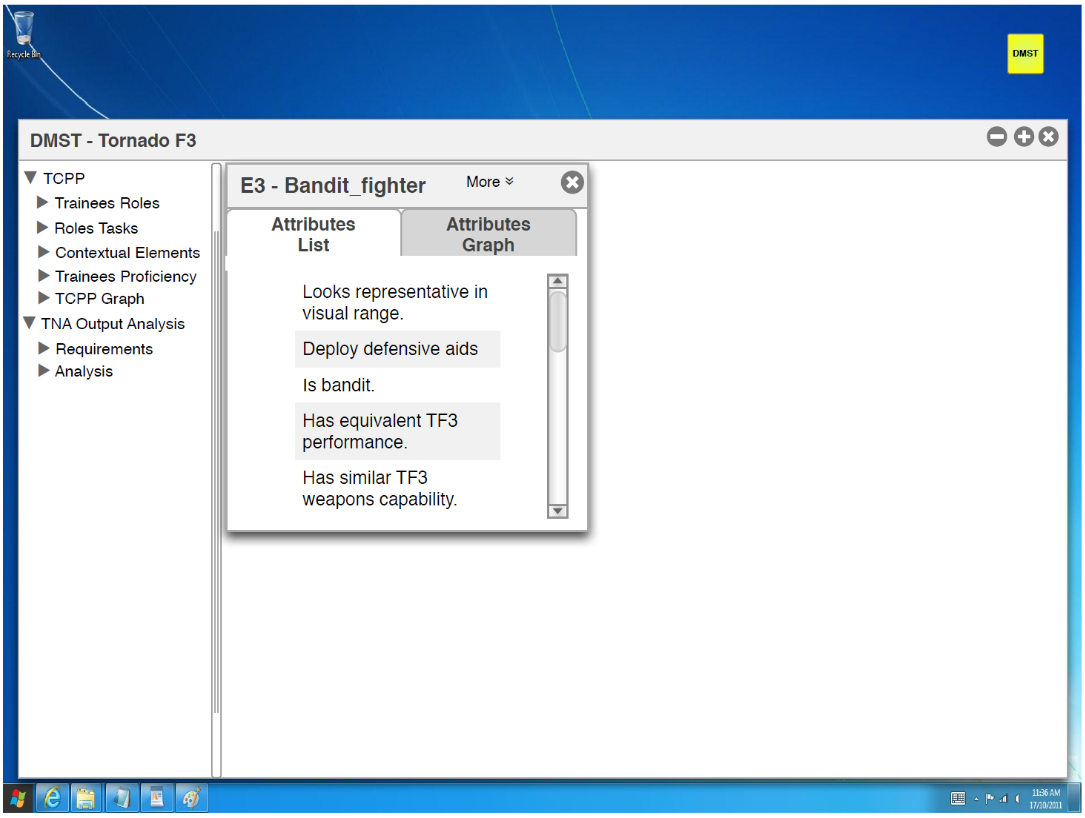

Figure 5.3 Snapshot from ToA demo that shows a list of attributes for a requirement's component ("bandit fighter") – Data Set 1

Figure 5.2 and 5.3 shows an example from the Case Study 1. The requirement component selected is 'Bandit fighter' and its attributes (e.g. looks representative in visual range; Deploy defensive aids; etc.) represent the characteristics that the component 'Bandit fighter' has to exhibit in training. These attributes represent the functionalities that the end training system, for example training media system, would have to exhibit.

The TNA analysed in Case Study 1 represents the training needs for a training exercise and therefore it comprises information on trainees' tasks, instructional and assessment specifications. The TNA analysed in Case Study 2 however, does not contain information on specific pilot tasks, instructional or assessment specifications, as this TNA is performed prior to a training exercise TNA. These differences, as previously mentioned, do impact on the way the ToA is used. This is explained below.

In Case Study 1, the knowledge resulting from the ToA can be used directly by the training designers (engineers) that, assuming that they have knowledge about technical capabilities and functionality of media, can start the process of functional to physical mapping the training environment system components (i.e function allocation) to satisfy the training requirements. On the other hand, in Case Study 2, the ToA output can be used to derive the assessment specifications and instructional tasks that will support the achievement of the training objective. Although the outputs can be used with different purposes, the analysis method is the same. This is illustrated in Figure 5.4.

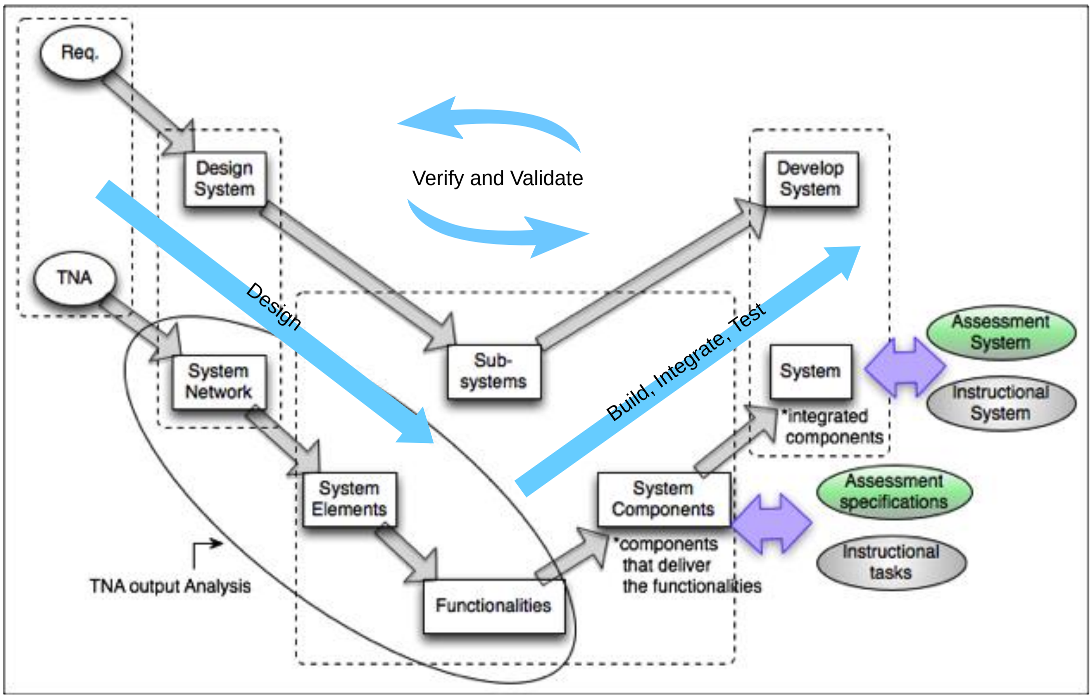

Figure 5.4 The place and role of ToA in the construction of training programmes (a SE perspective)

What determines the type of the output is the type of the input. If the input is more detailed, such as containing information about tasks and instructional methods then the output will display functionalities for training media. If the input is higher level TNA information such as, training objectives, then the ToA output will display characteristics to be used in establishing tasks and developing or selecting instructional methods and assessment strategies.

Figure 5.5 presents a snapshot form the ToA demo (through Cytoscape interface) that shows the Requirements network for Case Study 2. This was produced based on the information from Data Set 2. The specific document used to create the network was

'Training and Enabling Objectives Consolidated List'. The network shows the requirements components and the relationship between the components.

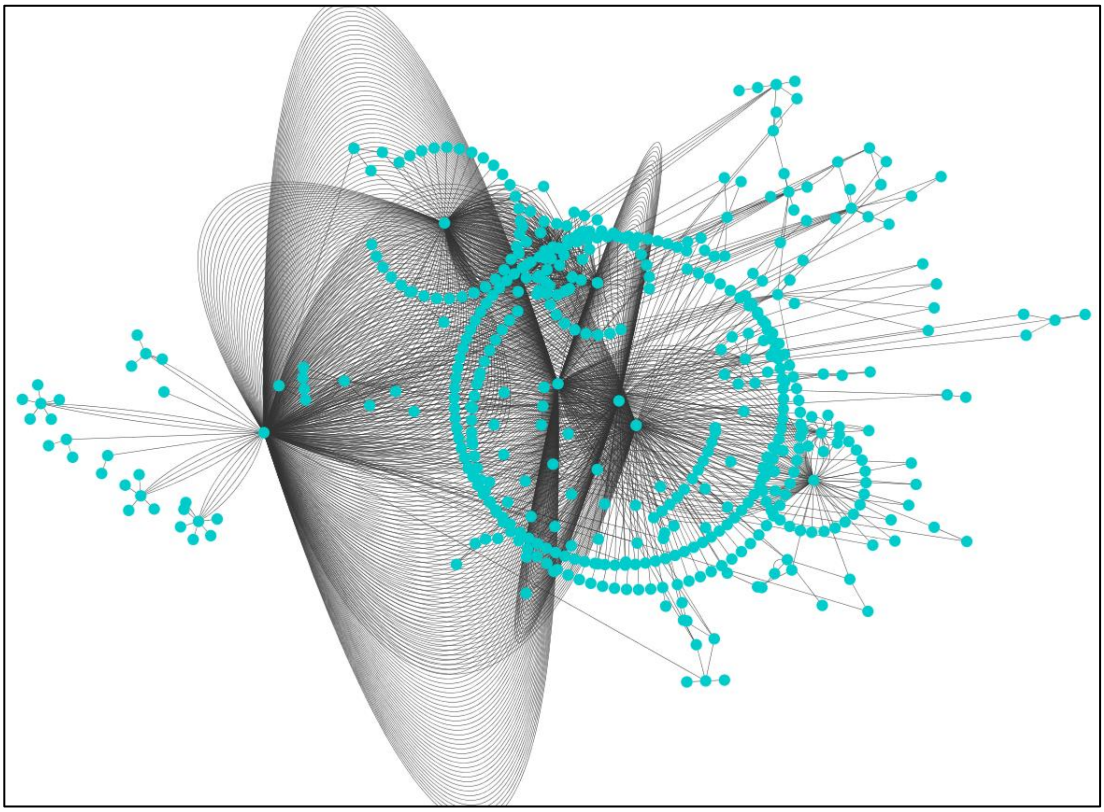

Figure 5.5 Snapshot from ToA demo (through Cytoscape interface) showing a network of requirements generated from Data Set 2 – 1st version

In the Case Study 2 requirements network shown in Fig. 5.5 there are multiple duplication overlaps. The duplications are an indication of the number of relationships and, therefore, highlight the components upon which the training is most focused. For example, in this case the training is more concentrated on the 'pilot' (principal node in Fig. 5.5) needing to 'describe' a series of 'methods' rather than on the 'pilot' needing to 'perform' a series of 'procedures'.

As in Case Study 1, the requirements network can be examined in depth by selecting individual requirements components and their attributes. An example is shown in Figure 5.6. A higher resolution version of the figure can be seen in Appendix 16.

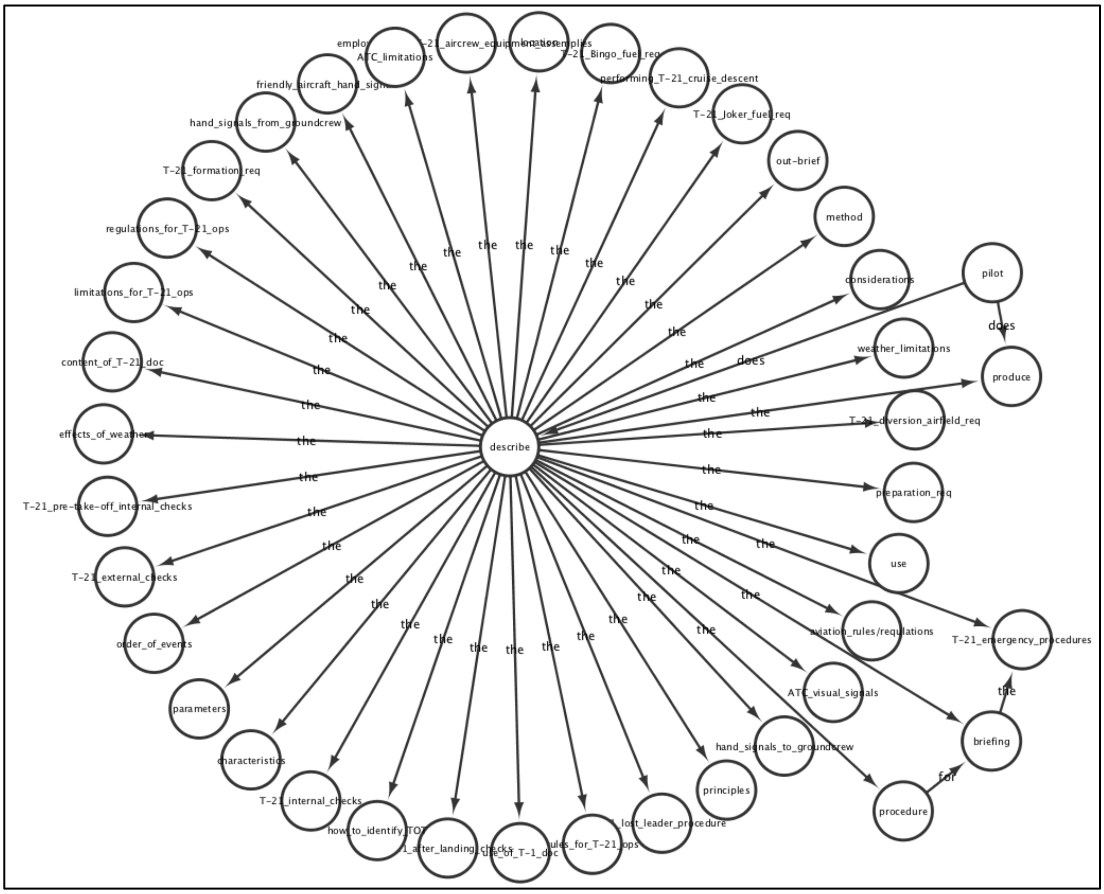

Figure 5.6 Snapshot from ToA demo (through Cytoscape interface) showing a requirement's component and its attributes (example from Data Set 2)

Figure 5.6 presents the attributes network of the requirement's component 'describe'. In this case, the attributes network highlights all that is required from the trainee to describe as part of the training. Based on this, decision makers that construct the training can start making decisions regarding what elements the training must contain that will enable this objective to be achieved.

There could be more than one suitable means to achieve a purpose. As such, it is essential that the purpose is examined in depth before any solution can be considered, and this is how the ToA method supports decision-makers, i.e. it supports the identification of means to satisfy the training needs through a more efficient management (including storage and visualisation) of the training needs.

The network visualisation software (Cytoscape) allows work with one network at a time. However, other information, if it becomes available, can be added to an existing network. For example, in Case Study 2, beside information extracted from the 'Enabling Objectives' document, other information related to condition, standards, difficulty, importance and Frequency of training tasks was added to the initial network of requirements. This particular information was selected from 'Condition and Standards' and 'DIF Analysis' documents (Table 5.1).

Although the Enabling Objectives were not connected directly to conditions, standard, difficulty, importance or frequency in the data set (the TNA), a network could be built based on their shared connection with the training tasks. This shows how the method can bring together information from various documents in one single place, where the information can be more efficiently stored, visualised and analysed. The network of requirements produced based on the Enabling Objectives, conditions, standards, difficulty, importance and frequency is presented in Figure 5.7.

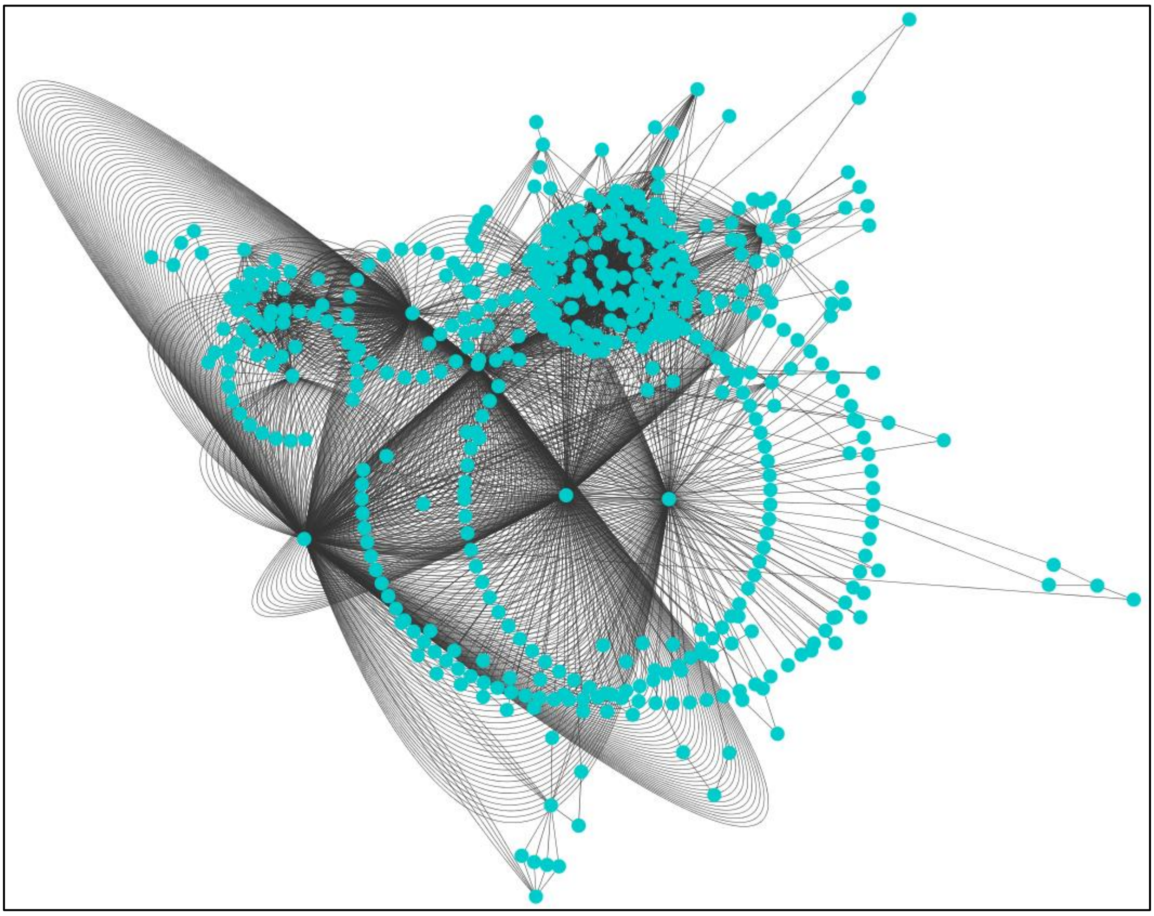

Figure 5.7 Snapshot from ToA demo (through Cytoscape interface) showing a network of requirements generated based on Data Set 2 - 2nd version

The network of requirements presented in Fig. 5.7 has 502 nodes, or requirements components and a total of 1695 links summing the requirements components attributes. As the ToA is at the level of concept, all the information was processed manually. As such, to fit the resource constraints, only the first 128 Enabling Objectives have been processed. The number of tasks taken to be furthered processed was decided arbitrarily.

The network summing the 128 Enabling Objectives, associated conditions, standards, difficulty, importance and frequency is shown in Figure 5.8. This network contains 174 nodes and 1181 links.

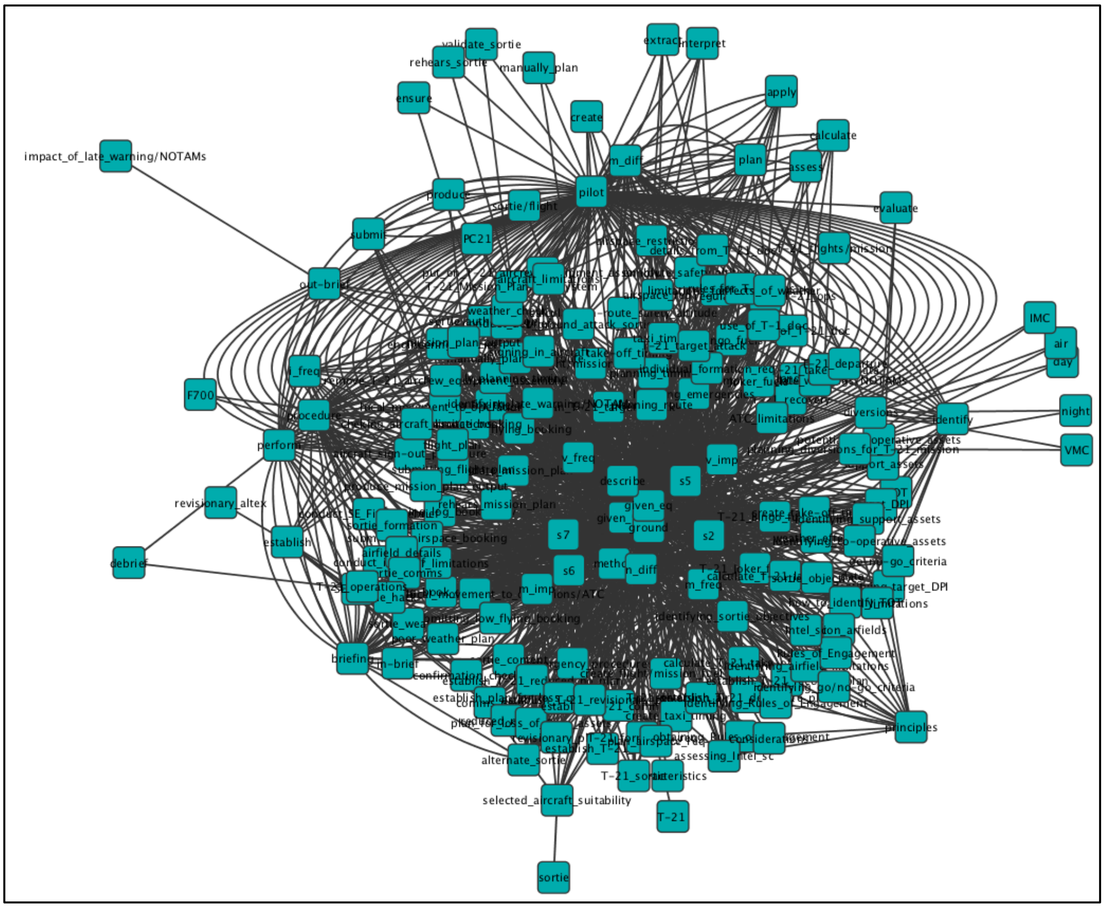

Figure 5.8 Snapshot from ToA demo (through Cytoscape interface) showing a selection of requirements' network (example from Case Study 2)

As previously mentioned, the requirements components and their associated attributes can be inspected separately, either by selecting them from the main network or from the list of components. An example of a requirement's component and associated attributes is shown in Figure 5.9 while a complete list of the components and their attributes can be found in Appendix 17.

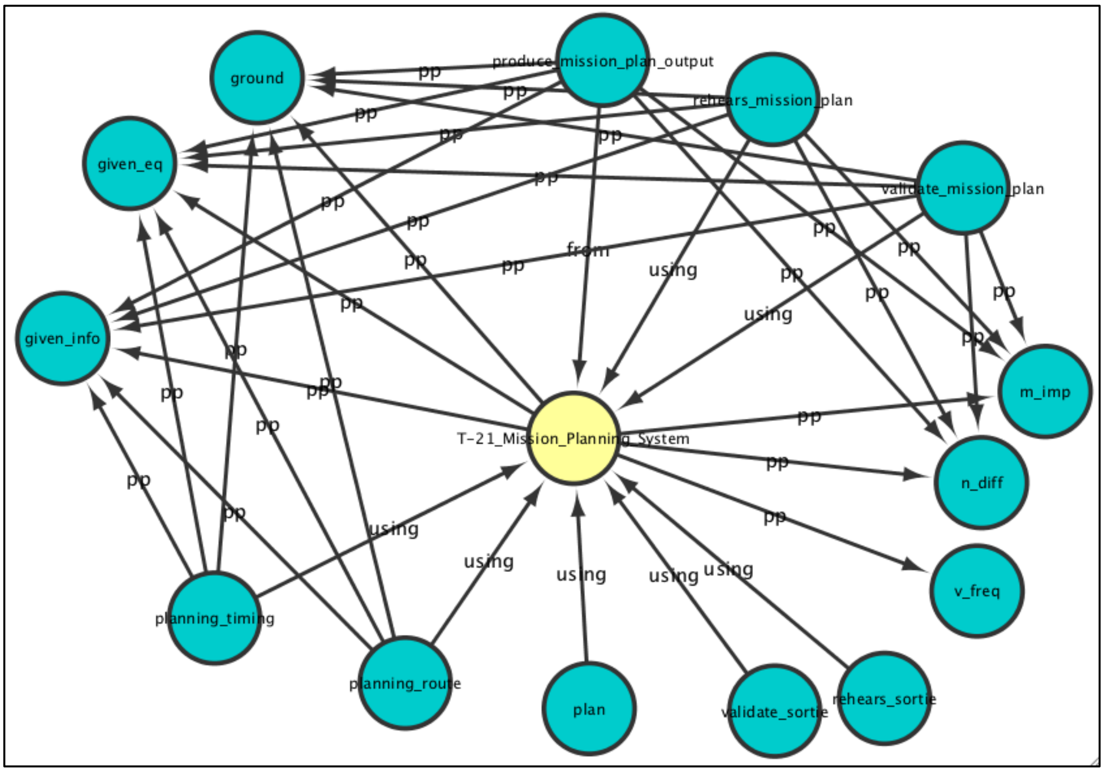

Figure 5.9 Snapshot from ToA demo (through Cytoscape interface) showing the "T-21 Mission Planning System" requirement's component and its attributes

5.3.3 Validation of TCPP and ToA

To demonstrate how the TCPP and ToA works and to facilitate feedback from the customer, a concept demonstrator was build and presented to the customer for feedback. For ease of demonstration, the two tools were presented as two separate modules in one concept-demonstrator system (DMSS).

As mentioned in the introduction of this chapter and discussed in Chapter 2 Methodology (section 2.3.4 Evaluation Studies), as part of the evaluation process the TCPP was presented to the customer as part of a demo. To facilitate this process a concept-demonstrator was built. The concept-demonstrator is a mock-up version of the tool that simulates how the tool works.

Customer feedback on high levels aspects of TCPP such as, functionality, compliance with requirements, general appearance and ease of use was requested following the demonstration of the tool. The form used to gather feedback from the customer can be found in Appendix 14. Customer feedback was positive, however at the moment of the demonstration only two people are available. Further attempts were made to engage the customer in the validation process (please see in Appendix 18 the questionnaire sent) however, feedback could not be gathered and analysed in time to be included in the thesis. Furthermore, other stakeholders, except BAE Systems could not be engaged in the evaluation process because the data set provided by them was given in confidence (could not be shown to third party). The system has to be further developed and applied to specific cases for more comprehensive validation tests to be performed.

5.4 Discussions and conclusions

In the Systems Engineering (SE) domain there are various techniques that can be employed to support evaluation and are commonly known as verification and validation methods and techniques. These can be classified according to two dimensions: formalism (informal, semi-formal and formal) and dynamic aspect (static vs. dynamic). Which technique is applied however will depend on factors such as: costs, time, intended use of the system, system users, data availability, required level of verification and validation, development approach and model maturity (Aarabi et al., 2011).

In general terms, verification procedures essentially are about checking if what was built (model, approach, tool) is right given the specifications (requirements and design parameters) while validation procedures are about checking if what was built is the right thing, if adequately supports its intended use (Aarabi, et al., 2011). Verification and Validation techniques are applied throughout the systems engineering process, starting from requirements to system components to the end system.

In terms of requirements and system evaluation, there are a couple of overlaps. For example, there is an overlap between system verification and requirements verification as system verification implies that what was built complies with the system requirements and requirements verification implies that the system requirements are satisfied (Bahill and Henderson, 2005). As such, checking requirements compliance is common to both requirements verification and system verification. Furthermore, there are also overlaps between requirements validation and system validation as, validating high-level requirements is similar with system validation (Bahill and Henderson, 2005). It has to be mention however that validation of low level, or technical, requirements is specific to system verification not system validation.

Dividing requirements into high-level and low-level is common practice in systems engineering (Bahill and Henderson, 2005), as to produce a complete and comprehensive set of requirements for a system it involves many parallel and iterative development loops. In general, high-level requirements can be described through terms such as: customer requirements, top-level requirements, system requirements, operational requirements, concept of operations, mission statement, stakeholder needs, stakeholder expectations; while low-level requirement are referred to as being: derived requirements, design requirements, technical requirements, product requirements, allocated requirements (Bahill and Henderson, 2005).

In the presented research, the requirements type and form for which the solution package was developed were high-level, a collection of customer needs and expectations regarding the production of a system that will support selection of media for construction training programmes rather that low-level, technical or design type of requirements. As mentioned in the previous chapter, early in the requirements development stage it was decided that research effort should not be spent on developing a complete and comprehensive system requirement set at this point in time because of the existing gaps in research and lack of resources. It was considered that this would be a futile research effort since a complete system solution was very unlikely to be built given the circumstances. The type of given requirements as well as the form and type of the proposed solutions (development or maturity level) did influence the type of verification and validation procedures that could be employed during the solution-evaluation stage.

The TCPP and ToA concept tools were evaluated through following:

- Verification of data flow in two separated case studies

- Face-to-face validation with the customer

The face-to-face validation procedure was supported by the creation of a concept demonstrator, which is a non-interactive simulation (mock-up interface build in PowerPoint) of an application (the DMSS) where both TCPP and ToA were run as two separate modules. The non-interactive simulation is a computer-based animation that presents what the users of the system would see when using the system (Beaudouin-Lafon and Mackay, 2003). The concept demonstrator was built in PowerPoint and the frames (the interface) were constructed in OmniGraffle. Customer feedback regarding the demonstrated concept solutions TCPP and ToA was positive in terms of the proposed system meeting their needs.

The two case studies show the TCPP and ToA potential to support decision-makers in constructing training programmes, either that is an exercise or a syllabus. The two case studies produced different types of outputs. This was because in Case Study 1, the TNA used was done for a training exercise and included information about assessment strategies and instructional tasks, while the TNA used in Case Study 2 was done for an entire training syllabus, prior to establishing training assessment and instructional related features. This demonstrates that the methods make use of generic and reusable templates and models.

In Case Study 1, the ToA was used to analyse the information resulting from a TNA done for a training exercise. The ToA method shows how this information can be analysed in a systematic way and could be transferred in a suitable form towards subsequent stages in the training design and development process such as, to the training design stage where decision makers are concerned with selection of training media systems to support training. This method can aid multidisciplinary team working and ensure a greater consensus within the decisions that are made during the process of constructing training programmes.

Furthermore, the TCPP offers a way through which training needs analysts can make decisions about tailoring the training exercise layout based on analysis of trainees' contextual proficiency profile. The TCPP however could not be performed in Case Study 2 because of the type of information available in Data Set 2. The information in this case was high level; the trainees were rated as having no or little previous experience. In this case, a TCPP analysis would add little to no value in assessing the trainees' gap in skills and knowledge before undertaking the next phase of training.

To apply the TCPP method, the analyst needs a sufficient level of information about the individual trainees experience and the context in which the trainee will have to operate, such as a scenario. The TCPP analysis is more usefully employed when decision makers are concerned with establishing what are the knowledge and skills gap, or readiness of pilots before starting a scenario type-task, either that is a training exercise or an operational mission. As such, it emerged that the TCPP has a wider applicability, such as, for selection of personnel for operational missions. The TCPP helps to identify the students, trainees or pilots' individual needs and facilitates the development of tailored training and/or tailored missions.

In Case Study 2, the ToA was used to analyse the TNA information resulting from needs analysis of a training syllabus. In this case, the ToA can be used to support the design and development of assessment methods and overall instructional strategy rather than choice of training media as in Case Study 1.

With the support of ToA, the decision-makers can have a better overview of the requirements because it provides a visual and holistic overview of the training requirements. The information that normally is included in a TNA is spread across multiple documents and usually that is in the form of text (see appendixes for Data Set 1 and 2). The ToA provides a way in which all this information can be gathered, managed and visualised in one place. The ToA not only captures these in one place but is also capable of showing the connections between individual components of requirements, which is an added benefit when it comes to the training construction engineer (designer) work, which is to trace and gather all attributes that a specific component is required to have only through consulting TNA documents.

The two methods, TCPP and ToA have been developed with the purpose of supporting the decision making process of constructing training by offering a way, or an approach, to manage high volume and complex information in a systematic and structured way. Furthermore, it offers a traceable and visible path of decision making by managing the information on which decisions rely.

The concept solutions proposed as a result of this research support the decision making process of selecting training media to construct training programmes by encouraging the decision makers to select systems functions before selecting the physical system and supports decision makers to systematically explore the solution space. These methods will perhaps enable new and more efficient training media systems to be selected or developed and, furthermore, drive innovation in terms of construction and/or selection of mixes of media to deliver training.

Chapter 6

Discussions

This chapter provides a reflection on the research that has been conducted, while also covering the limitations associate with the techniques employed and the outputs produced. The research that has been performed is summarised in Section 6.1, characteristics of the proposed support solutions is covered in Section 6.2, followed by the limitations of the research outputs in Section 6.3. A chapter summary is provided in Section 6.4.

6.1 Summary of Research

Initially, the focus of the research was orientated towards developing an approach through which the selection of the training media could be optimised. However, the optimisation route was dismissed, as previous studies showed that there are other underlying problems that need to be solved, such as, identifying and quantifying the effects of factors involved in the decision-making of selection of media for training, so that a model of the decision-making problem can be built, to which an optimisation technique can then be applied. As a result, the aim of the research was shifted towards understanding the decision-making problem of media selection to construct training programmes and development of support solutions.

To achieve the aim of the research and stay within the scope of the project, two main research topics were set to be explored to identify the gaps in current knowledge:

- Identify the challenges in selecting training media to construct pilot training programmes
- Define the needs of the decision-makers

A pragmatic research philosophy (as depicted by Creswell, 2009) was considered to be the best approach to be taken in the case of the presented research. That is because neither the positivist nor the constructivist approach could satisfy the research project requirement of producing a solution, while supporting research that will answer the stated research questions. It was identified that a mixed methodology approach would be more suitable to follow.

As such, a mix between qualitative and systems engineering specific methods and processes was adopted (Table 2.4 Employed research methods, in Chapter 2). Qualitative research was considered to be appropriate as this approach is concerned with exploration of aspects that are difficult to quantify (Brink, 1996) and systems engineering specific methods where employed to develop the concept-solutions TCPP and ToA.

In terms of Mixed Methodology literature this approach is in lines with what is called a Sequential Exploratory Strategy, usually employed when developing a tool or an instrument. Since the systems engineering approach is fundamentally similar (in structure) to the sequential exploratory strategy and employed with the same purpose (to develop a solution) it was decided that a combination between the two will be beneficial.

In the initial phase of research, the 'Industry perspective' case study, a qualitative specific method, was employed to explore the subject under investigation and gather information regarding the challenges specific to pilot military training industry. This step in the research informed the next one where the requirements for a possible support solution system were gathered. Requirements elicitation is a SE specific process, employed to define and understand the problem. From a SE perspective the 'problem' is defined through the process of identifying the customer needs which are translated into customer requirements. The way requirements are usually gathered is by employing qualitative specific methods such as interviews and observations.

It was decided that a data-analysis qualitative approach, such as grounded theory analysis, was more efficient as a method of analysing the requirements. This was because developing a complete and comprehensive set of requirements involves many parallel and iterative developments that would have put a strain on the time allocated for the research and would not have brought too much benefit to the overall research since the system required to be built is unrealistic, given the resources and the extant knowledge.

The customer needs were grouped in desired capabilities. Four main groups were identified, that can be expressed as:

- The need for a supporting link in transferring the training requirements from the analytic (TNA) phase to the Design phase of training construction
- The need to support the training programmes to be tailored for specific pilot needs
- The need to support the assessment and selection of training media
- The need to support the connections between training methods and training media

Following the exploration of the problem area and identification of gaps in knowledge, a set of research questions were set to be answered by this research:

1) How can training media be differentiated?
2) What is the role of media and method in training?
3) How can the differences between trainee's previous experiences be identified?
4) How can TNA information be managed?

What remain outside the scope of the research was:

- Assessment of training media
- Transfer of TNA information from the analytic phase to Training Design phase, though issues concerning the vast amount of TNA output has been addressed

Considerable effort was put into analysing the relationship between some of the main concepts underlying the decision-making problem of media selection, which are: the media, the instructional methods and the cognitive process of learning. As a result, a series of for models were produced, in which different aspects of the relationship between media, method and learning are mapped out. These are:

- A cognitive perspective of the interaction between media and the learner (Fig. 4.12 in Chapter 4)
- A model mapping the interactions between Training Media, the Learner and the Instructional Methodology (Fig. 4.14 in Chapter 4)
- A new proposed strategy towards Training Media Selection (Fig. 4.15 in Chapter 4)

- A unified selection framework of Instructional Process (Fig 4.16 in Chapter 4)

Furthermore, research was orientated towards producing a multidimensional classification framework of training media.

These research outputs (the models and frameworks) are concept solutions proposed to support further research in the domain as well as to offer support for media selection and training construction by offering insight into some of the connections between some of the factors such as media characteristics, method and trainee's cognitive process, which were identified as being important in media selection and training programme construction.

Research effort was also allocated to providing solutions for the expressed industry needs of bridging the gap between the analytic stage and the technical/design stage when it comes to training requirements transfer, and the need to support tailoring the training programmes to individual pilot.

For the requirements transfer issues, a novel method of managing and visualising requirements was proposed to support not only the transfer of requirements but also to enhance storage, manipulation and visualisation of requirements; the ToA method.

To address the need to provide a solution to support construction of training programmes tailored on individual pilot needs, the literature concerning competence and competency assessment was explored and a method to analyse the pilots contextual proficiency profiles, the TCPP, was developed.

Two data sets were used to verify the TCPP and ToA. The TCPP and ToA were validated by presenting the concept to the customer and demonstrating the methods through a concept-demonstrator, a non-interactive simulation method used to facilitate face-to-face validation. All models and framework have been presented to the customer, as well as this thesis, for feedback and comments.

6.2 Characteristics of the Proposed Support Solutions

Though at the stage of concept, the solutions developed potentially could provide valuable support to decision makers when selecting training media and constructing training programmes, either used individually or in combination. The concept solutions have been developed with due consideration to the challenges faced by decision makers and issues surrounding the decision-making problem of training media selection and construction of training programmes.

The ToA and TCPP support solutions are data-driven information managing systems that were designed to provide support for decision-makers at the analytic stage in the decision-making process. The ToA analyses the training requirements information and offers the possibility of easy transfer of this information to the design stage in the training construction process. The TCPP analyses the information regarding proficiency of individual trainees and assesses their readiness to undergoing, or undertaking, specific training exercises or operational missions so that training can be tailored accordingly.

Furthermore, the Training Media Classification Framework offers a model to classify and store information about various training media and the Media Selection Framework proposes a novel approach to media selection. The other developments, such as the interaction maps between training method, media and the learner, support the decision-makers by offering insight into the relationship between factors upon which the decision-making relies. The interaction maps can contribute towards reducing the intrinsic complexity that characterises the decision-making of media selection.

According to Keen and Scott Morton (1978) description of Management Information Systems (MIS), which is primarily based on the support offered to decision makers rather than on type of problem that they are used for, it could be said that the ToA and TCPP are MISs that support the decision making process through provision of necessary information. The ToA and TCPP gather information (or data) from disparate sources and documents to which developed rules and data processing existing algorithms are applied so the information is gathered and structured in such a way that new knowledge is produced.

The ToA and TCPP offer descriptive information and facilitate sense-making through the management and analysis of relevant information that otherwise would be harder to grasp due to human cognitive limitations; i.e. offer support for problems where information is beyond human capability of analysis.

This is beneficial because the information necessary to make informed decisions is already in high volumes and on the rise especially as more information becomes available (e.g. new developments in training technology). This puts a strain on the decision-makers that will need support not only with the decision-making process but also with making sense of all this information. Storage, managing and analysing information in a meaningful way is a must in this information era and perhaps necessary before embarking on optimising a decision-making process where the decision relies on vast quantities of data.

6.3 Limitations of Research

The research presented in this thesis has provided some very useful outputs. There are however, limitations associate with the techniques employed and the outputs produced.

In the case of qualitative methods, such as interviews, observation and case studies, they have inherently limited generalisability and the results obtained by employing these methods are relevant to the specific context in which the studies took place (Creswell, 2009). In other words, the findings regarding the challenges and needs of pilot training industry to select training media and construct training programmes are specific to the community in which the study took place and might have limited relevance to wider industry. Furthermore, this limited the research to UK pilot training.

In the case of critical reflection and deductive reasoning used to combine existing knowledge to produce new knowledge the key limitation is that the researcher makes the assumption that the existing knowledge (statement, theories, results) is true. These types of methods are not used to test existing ideas, theories or hypotheses but to generate new ones. Furthermore, it is used to clarify and interpret existing findings and syntheses these into a conceptual framework. However, it lacks rigorous testing of outputs necessary to prove the new generated concepts or ideas.

Regarding concept analysis, Walker and Avant (1995) draw attention to the fact that the new generated concept of definitions are limited in terms of construct validity (lack of measurement) that accurately reflects a theoretical base. The lack of rigor as underpinned by quantitative research is a general critical aspect of qualitative research (Mashele, 2009).

For evaluation of the developed concepts various methods and techniques were used such as data flow verification, face-to-face validation through non-interactive simulation and output validation through requirements verification. These have been run with two sets of data in two separate case studies. Though these are appropriate techniques to be employed given the characteristics of the outputs (discussed in Chapter 2: Methodology) and available resources, they do have inherent limitations. The underlying issue with these methods and techniques is that they are subjective in nature, i.e. they rely on subjective judgement of the evaluators and are confined to the types of data that were used for verification. Ideally, a more diverse set of case studies would be utilised (i.e. with data from other types of training, not only pilot).

6.4 Summary of Chapter

This chapter has revisited the research conducted in this PhD project and summarises the research outcomes. A description of the research outputs was provided and the limitations of the research discussed.

Chapter 7

Conclusions

This chapter concludes the thesis by providing an assessment of the fulfilment of the research objectives in Section 7.1, followed in Section 7.2 by an evaluation of how the research questions have been addressed. An overview of the research contributions in given in Section 7.3, with reflections on the PhD project and an outlook on future work in Section 7.4, before finalising with concluding remarks in Section 7.5

7.1 Assessment of objectives

To achieve the aim of the project and to answer the research questions a number of objectives were identified (as stated in Section 2.2 of Chapter 2). The way and extent to which these objectives have been achieved is as follows:

Objective "1. Investigate the problem area through literature review" has been achieved by conducting literature review on multiple domains related to construction of training programmes, selection of media and decision support systems (DSSs). The literature review revealed that within the process followed to construct a training programme, the issue of selection of training media is treated at two separate levels: first at an analytic level, then at a design (technical) level. Regarding, the training media selection, the approaches and tools evolved over time from paper to computer based, however, the strategy has remained relatively the same: selection of methods then selection of media. Review of the literature regarding DSS revealed that there are various ways and different utilisation for which a DSS can be constructed. The DSS literature review helped to define the support solutions developed by this research, while the overall research, concepts and theories identified through the wider literature review (including the ones not specifically included in Chapter 3) helped to produce the developed support solutions.

Objective "2. Investigate the problem area from industry point of view" has been achieved by conducting a case study where the problem of media selection and construction of training programmes has been investigated utilising various research methods such as interviews, observations and review of industry relevant documents.

The results of the study showed that the decision-making of selecting the media for constructing training programmes relies mainly on the subjective experience of SMEs and that that is due to the lack of facilitators (support) for a more objective decision to be made, i.e. there is a lack of awareness of the implication and use of certain training media; it is difficult to grasp the entirety of factors that affect the choice; difficulties in differentiating between various types of training media; difficulties in transferring requirements across domains.

Objective "3. Document the issues and gaps extant in practice and theory" has been achieved by documenting the findings following the investigation of problem area and of the case study mentioned above. The findings were summarised in Section 1.3 in Chapter 1.

Objective "4. Gather, analyse and validate stakeholders' requirements" has been achieved by gathering and examining the stakeholders' needs. These are presented and discussed in subsection 1.2.3 in Chapter 1. To reiterate, the requirements analysis was done only at high-level as it was considered that further analysis and iterations will not add value to the present research project.

Objective "5. Develop decision support solutions" has been partially achieved through the development of solutions presented in Chapter 4. The developed solutions however are at an incipient level in their development, at the level concepts, and further research is needed to test and further develop them.

Objective "6. Evaluate the proposed solutions" has been partially achieved. The evaluation procedures are discussed in Chapter 5. The evaluation was based on a number of techniques discussed in Chapter 2, Methodology. The methods and techniques used were selected based on level of development of solutions and available resources.

7.2 Answering the research questions

Achievement of the research objectives stated earlier enabled the research questions set at the beginning of the research to be answered. The completion of research objectives, as well as the way in which they were achieved, influenced the type and breadth of the answers of the research questions.

Question 1: “How can training media be differentiated?”

A multidimensional framework has been produce that enables classification of training media passed on their characteristics such as: cognitive, economic and technical attributes; type of device (software, hardware) and type of environment (Live, Augmented, Synthetic).

Question 2: “What is the role of media and method in training?”

A cognitive approach of the relationship between media, method and the learner has been provided and a model that maps this type of interaction was produced. This view advocated for a stronger influence of media on the training process than previously thought. This influence is supported by studies in the literature that shows that media can provide cognitive efficiency and influence the type of instructional method. To support decision-makers (such as trainers and training analysts) in understanding and perhaps use this knowledge in constructing training programmes, a model that maps the interactions between media, the learner and method was produce alongside an approach to training media selection and unified framework for selection of instructional methods.

Question 3: “How can the differences between trainees’ previous experiences be identified?”

An approach with supporting tool (TCPP) was developed to support the decision-makers in identifying the specific areas where trainees have, or not have, a lack of skills and knowledge and to what extent. TCPP provides the trainee profile based on an assessment made between tasks to be performed and in which circumstances the trainee has or not performed those tasks before.

The TCPP allows examination in detail of the readiness of the trainee given the training scenario so that judgements can be made about the complexity needed for the training exercise and decisions can be made about the physical aspects of the training environment.

Question 4: "How can TNA information be managed?"

A concept tool has been developed to manage the ToA outputs. The tool was developed based on Systems Engineering (SE) principles of writing requirements and English structure language. Furthermore, the ToA employs a network visualisation technique to display the information in a dynamic way. As such, the proposed tool offers a network-like view of TNA, gathered in one place, with the options of examining individual information and the links between various types of TNA information.

7.3 Summary of contributions

Much insight has been gained throughout this research work and new understanding has been created regarding some of the issues and challenges characterising this decision-making problem of media selection for constructing training programmes. Furthermore, a set of support solutions have been developed and proposed to address some of the identified issues and challenges.

The novelty elements of the research presented in this thesis, achievements and contribution of these to the field of research and industry alike are summarised below:

- The present research has produces a novel way in which research paradigms and methods appertaining to various disciplines (Human Factors, Systems Engineering, Information Systems) have been combined and used in the research to explore the problem, derive solutions and evaluate them.

- The present research has made use of network visualisation tools from biology (e.g. Cytoscape) as a novel way to manage and represent large and complex amount of information (the ToA) necessary for selection of training media and training programmes construction (such as TNA information) to possibly facilitate transfer of information from the analytical to design training domain and increase the situational awareness of decision makers. In addition, the present research developed a software-based concept tool to support the management and visualisation of this information.

- The present research has used existing theories related to memory (Atkinson and Shiffrin, 1968) and instructional methods (Gagne, 1977; Sugrue and Clark, 2000; Salas, 2001) to develop a unified process framework of instructional process (the Instructional Process Framework) that could be used as reference (guidance) by instructors when deciding which instructional methods should be selected.

- The present research has used Human-Machine communication theories (Shannon-Weaver Model of communication and Hollnagel and Woods Extended model of communication) and the cognitive model of media (Kozma, 1991) to develop a cognitive communication model that maps the interaction between the learner and the media (the Media-Cognitive System Communication Model; the Media System-Cognitive System-Instructional Methodology Interaction Map), which were further used to develop a new approach towards media selection (the Media Attributes – Instructional Method Map, and the Media Selection Framework).

- The present research has developed a multidimensional classification framework of training media (the Training Media Classification framework) to support definition and classification of current and future training media systems. It is hoped that if adopted by the wider community that the framework will help solve some of the misunderstandings between domains when referring to training media, and foster research in the training media domain and support decision-making regarding training media selection.

- The present research has developed a technique to map and visualise the trainees' skills and knowledge (the TCPP) in report with the new operational tasks and environment in which they will need to be performed, which could help in tailoring the training to the individual. Furthermore, this technique could potentially be used also in selecting potential personnel for operational missions.

Part of the research work done has been presented at local (Loughborough University annual PhD conferences) as well as international conferences (22nd Annual INCOSE International Symposium and the 7th International Conference on Systems of Systems Engineering, IEEE SOSE, 2012). These are presented in Appendix 19 and 20. Further academic papers are currently being prepared, which will present the work related to development of media, cognitive system and instructional method interaction maps, training media classification framework, TCPP and ToA.

7.4 Reflective thoughts and looking forward

Though this research project started having a clearly defined purpose, that of developing an approach with a support framework or tool through which the selection of training media could be optimised so as to ensure the complete satisfaction of training objectives using the most appropriated blend of training media, it came to light during the research process that the scope is very wide and that there is not enough knowledge to properly bound and map the decision-making problem of training media selection so that a satisfactory optimisation approach could be developed. Because of this, a considerable amount of time (upon reflection, maybe too much) was spent investigating the subject matter and scoping the problem area for this research to address.

While investigating, defining and mapping a problem area that is not fully known or understood is worthwhile, and will benefit the research and industry alike, it would not have entirely satisfied the requirements of the project. Furthermore, investigatory work can lead the researcher into areas that lack familiarity (no previous experience with) and this in turn requires that extra time is allocated to familiarise oneself with the new concepts and research areas. This challenge was overcome by staying focused on the overall purpose of the project and directing the research efforts in those areas where the author felt that she could make a contribution. In hindsight though, it probably would have been more beneficial in scoping and focusing the research into fewer areas rather than trying to provide answers for all the identified issues. As the research time and resources are limited this approach of trying to provide answers for all the identified issues affected the depth in which those issues were addressed and ultimately the level of development of the proposed solutions.

The level of development of the proposed solutions was also affected by the limited access to data that was experienced during this research project. Though the industrial partner offered valuable information and support throughout the research, access to data is paramount to understand the problem, develop and test solutions. This challenge has been overcome partially by use of data collected mainly from literature; however, for future studies access to data (type, amount, timing, etc.) should be discussed and agreed before any research scoping exercise.

The breadth of the problem area that this research addresses and the resource limitations mean that inevitably there are many more areas in which more work could and should be done. The research work carried out to produce this thesis highlighted areas where future work needs to be concentrated, as well as areas of work that leads on from the research work carried out so far. These are summarised below.

- Research needs to be carried out into documenting and mapping in detail the decision-making process of training programmes construction (including media selection) from the beginning (analytic phase) to the end (design phase). To accomplish this, the researcher needs to have access to data and to the decision-making process in its entirety.

- The developed frameworks of media, instructional method and cognitive system need to be further tested within media selection and training construction projects. It needs to be evaluated and further developed based on the results.

- The developed Training Media Classification Framework needs to be further tested within a considerable pull of training media examples to evaluate its practical usefulness. Access to training media examples (from developers, manufacturers and users) has to be available.

- The TCPP concept solution has to be further developed into a software-based tool and applied to more case studies. Results of evaluation following these studies should be used to further develop the TCPP method and tool and tailor it according to the domain of activity (e.g. other types of training or training stages except the fast-jet mission training).

- The ToA concept solution has to be further tested and validated with potential stakeholders (i.e. in between teems communication – analysts and engineers) and further developed, based on the results, into a software-based tool.

7.5 Concluding remarks

There are several contribution to knowledge made by the research presented in this thesis to the area of selection of training media and construction of training programmes as well as to development of solutions to support decision-making in this area. However, the problem that initiated this research project is still unresolved. That is because optimising the decision-making problem of training media selection without fully understanding the problem to optimise is a futile exercise.

While research interest towards solving this problem has recently resurfaced within the industry as more and more training media technologies are developed, within research few advances have been made. A problem might be the access of mainstream research to data and information related to this specific subject as well as limited access to research and studies performed within the industry. Though this situation is understandable, because access to this type of information has security and commercial considerations, it inhibits a more rapid development of solutions.

The research presented in this thesis highlights some areas considered to be of high interest for research and puts forwards some novel ideas in terms of possible solutions that could support the decision making process of training media selection and construction of training. Though academically valuable the research conducted so far provides conceptual support solutions that have limited value for industry, and require instantiation in executable software tools.

Practical problems require practical and usable solutions and therefore there is an urgent need to develop the concept solutions proposed by the research presented in this thesis into decision support tools to be used in the area of training media selection and construction of training.

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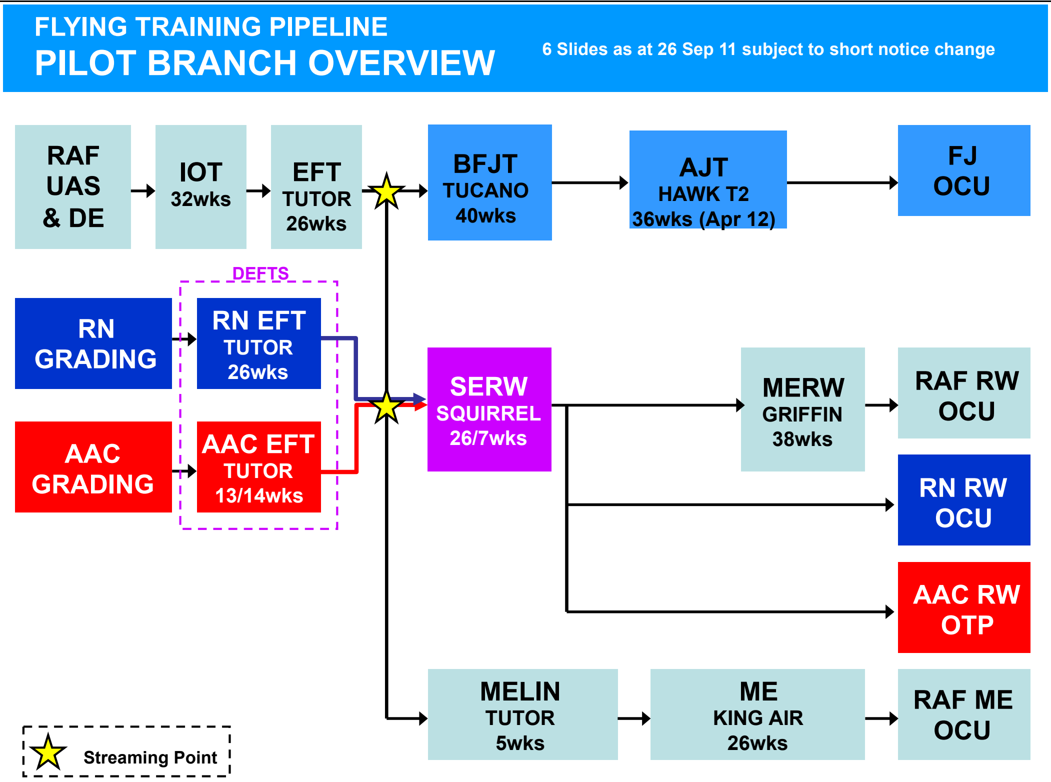
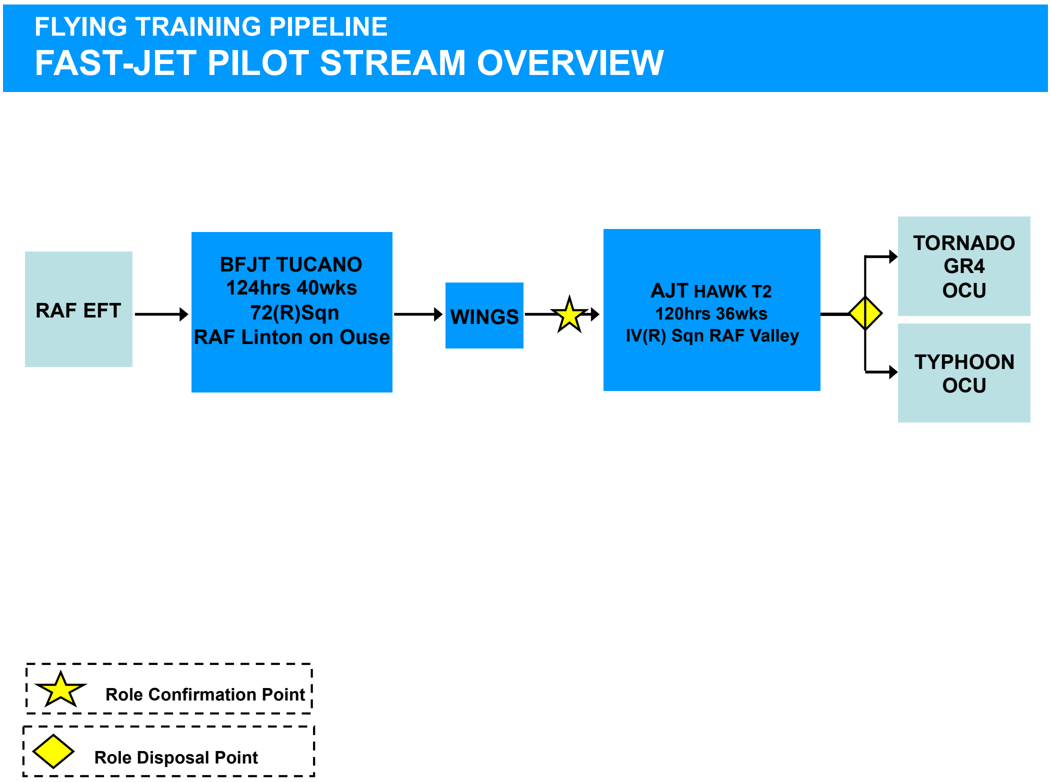
www.bnhexpertsoft.com - BNH Expert Software

Appendices

Appendix 1: RAF Flying Training Pipeline (www.raf.mod.uk)





Appendix 2: Pike and Huddlestone (2011) Training Media environments breakdowns

Type of simulation	Definition	Example
Virtual	Virtual simulation can be defined as "real people operating simulated equipment in a virtual environment".	Vehicle and ops room simulation.
Constructive	Constructive simulation can be defined as "real people exercising military decisions on the basis of information constructed by a computer system."	A common type of constructive simulation is te classic wargame and is typified by the wargames such as the one supporting the Command and Staff Trainer (CAST) and the Land Warfare Centre.
Live Simulation	Live simulation can be defined as "real people operating real equipment with simulated effects in a live environment".	It is typified by the use of instrumented flying ranges and the Tactical Engagement Simulation (TES) systems used at BATUS.
Embedded simulation	Embedded simulation is the incorporating of simulated capacity into operational equipment.	Simulation modes built into warfare systems would fall into this category.
Networked simulation	Networked simulation is the networking together of multiple simulators.	Examples include the Combined Arms Tactical Trainer (CATT) and the Medium Support Helicopter Aircrew Training Facility (MSHATF), both of which have multiple vehicle simulators connected together on one site.
Distribute simulation	Distributed refers to the networking of simulators and simulator networks across different sites.	Examples include the connection of the Cooke Warfare Team Trainers in Portsmouth being connected to US Navy simulation systems in Norfolk, Virginia and the connection of the Mission Training by Distributed Simulation (MTDS) system at RAF Waddington being connected to equivalent USAF systems in Mesa Arizona.
Synthetic Wrap	Synthetic wrap is an ingenious combination of the use of live and virtual simulation to provide an extended battlespace for training. This enables Operational pictures to be populated with elements that are outside the geographical area being used for training. The challenge is transforming an element traversing the constructive space into the live specie.	
Augmented Reality	Augmented reality refers to the technique of integrating synthetic elements into the live environment.	A typical example might include the insertion of synthetic target images and weapons effects into a weapons display.

Appendix 3: Melton and Bahlis (2013) Media Breakdown

Instructional Objectives/Outcomes

Category	Media	Support Knowledge Objectives	Support Mental Skill (Problem Solving) Objectives	Support Physical Skill Objectives	Support Attitude Objectives	Support Software Objectives	Support Initial Training	Support Certification	Support Orientation	Lead to t High Proficiency (Mastery) Level	Facilitate Information Retrieval (Reference Tool)	Facilitate Content Memorization	Convey Complex/Abstract Concepts	Support Advanced Instructional Strategies	Faciliate Interaction with Equipment/Software
Instructor-led	Instructor-led Classroom	Y	Y	Y	Y	S	Y	Y	Y	Y	S	S	Y	Y	S
	Instructor-led On-location [On-the Job]	Y	Y	Y	Y	S	Y	Y	Y	Y	S	S	Y	Y	S
	Instructor with Computers [Electronic Mediated Classroom]	Y	Y	Y	Y	Y	Y	Y	Y	Y	S	Y	Y	Y	Y
	Instructor with Equipment	Y	Y	Y	Y	Y	Y	Y	Y	Y	S	Y	Y	Y	Y
Print	Print	Y	S	N	N	N	Y	Y	Y	N	Y	Y	S	S	N
	Print with Computer	Y	S	N	N	Y	Y	Y	Y	S	Y	Y	S	S	Y
	Print with Equipment	Y	S	Y	N	Y	Y	Y	Y	S	Y	Y	S	S	Y
Tapes	Audio Tapes [MP3] [iPod] (with Handouts)	Y	N	N	S	N	Y	Y	Y	N	S	N	N	N	N
	Video Tapes [DVD]	Y	S	Y	S	N	Y	Y	Y	N	S	N	Y	S	N
	Video Tapes [DVD] with Computers	Y	S	N	N	Y	Y	Y	Y	S	S	S	Y	S	Y
	Video Tapes [DVD] with Equipment	Y	S	Y	S	Y	Y	Y	Y	S	S	S	Y	S	Y
CBT/WBT	Level 1 Interactive Courseware (ICW) - Passive	Y	N	N	N	N	Y	Y	Y	N	S	N	N	N	N
	Level 2 Interactive Courseware (ICW) - Limited Participation	Y	N	N	N	S	Y	Y	Y	N	S	S	N	N	N
	Level 3 Interactive Courseware (ICW) - Complex Participation	Y	S	S	S	Y	Y	Y	Y	S	Y	Y	S	S	Y
	Level 4 Interactive Courseware (ICW) - Real Time Participation	Y	Y	Y	S	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
EPSS	Intelligent Tutor [Serious Games]	O	Y	Y	S	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Embedded Training Appended	Y	Y	Y	N	Y	N	N	N	S	Y	S	Y	Y	Y
	Fully Embedded Training	Y	Y	Y	N	Y	N	N	N	S	Y	S	Y	Y	Y
	Hypertext [Google]	Y	N	N	N	Y	N	N	N	N	Y	N	N	N	S
	Hypermedia [You Tube]	Y	S	S	S	Y	N	N	N	N	Y	N	N	N	S
	Electronic Performance Support System (EPSS)	Y	Y	Y	N	Y	N	N	N	S	Y	S	S	S	Y
Conferencing	Audio Conferencing (with Handouts)	Y	N	N	S	S	Y	N	Y	N	S	N	N	N	N
	Computer Conferencing	Y	Y	S	S	Y	Y	Y	Y	S	S	S	S	S	S
	Video Tele-Conferencing	Y	Y	S	Y	S	Y	Y	Y	S	S	S	S	S	S
	Video Conferencing	Y	Y	S	Y	S	Y	Y	Y	Y	S	S	S	S	S
Internet	Internet Virtual Classroom [Virtual Learning Space]	Y	Y	S	S	Y	Y	Y	Y	S	S	S	S	S	S
Trainers	Level 1 - Desk Top Trainer	E	Y	Y	S	Y	Y	Y	Y	Y	S	Y	Y	Y	Y
	Level 2 - Part Task Trainer (FTD: Levels 1 to 6)	E	Y	Y	S	Y	Y	Y	Y	Y	S	Y	Y	Y	Y
	Level 3 - Full Task Trainer (FFS: Level C)	E	Y	Y	Y	Y	Y	Y	Y	Y	S	Y	Y	Y	Y
	Level 4 - Full Task Trainer (FFS: Level D)	E	Y	Y	Y	Y	Y	Y	Y	Y	S	Y	Y	Y	Y
Virtual Reality	Virtual Reality Level 1 - Augmented	E	Y	Y	Y	Y	Y	Y	Y	Y	S	Y	Y	Y	Y
	Virtual Reality Level 2 - Partially Immersive	E	Y	Y	Y	Y	Y	Y	Y	Y	S	Y	Y	Y	Y
	Virtual Reality Level 3 - Fully Immersive	E	Y	Y	Y	Y	Y	Y	Y	Y	S	Y	Y	Y	Y

Design Constraints

Media	Facilitate Creative Design/Presentations	Offer Multiple Paths for Content Mastery (Diverse Skills)	Accommodate Trainees with Limited Reading Ability	Easy to Scale [Delivery Time = Critically Short]	Simple to Update	Up-Front Investment Requirements	Training Material Development Time Requirements
Instructor-led Classroom	Y	S	Y	S	Y	L	L
Instructor-led On-location [On-the Job]	Y	S	Y	S	Y	L	L
Instructor with Computers [Electronic Mediated Classroom]	Y	S	Y	S	Y	L	L
Instructor with Equipment	Y	S	Y	S	Y	L	L
Print	S	Y	N	Y	Y	L	L
Print with Computer	Y	Y	N	Y	Y	L	L
Print with Equipment	Y	Y	N	Y	Y	L	L
Audio Tapes [MP3] [iPod] (with Handouts)	S	S	S	Y	S	L	L
Video Tapes [DVD]	Y	S	S	Y	N	M	H
Video Tapes [DVD] with Computers	Y	S	S	Y	N	M	H
Video Tapes [DVD] with Equipment	Y	S	S	Y	N	M	H
Level 1 Interactive Courseware (ICW) - Passive	N	S	N	Y	Y	L	L
Level 2 Interactive Courseware (ICW) - Limited Participation	N	S	S	Y	Y	L	L
Level 3 Interactive Courseware (ICW) - Complex Participation	Y	Y	Y	Y	S	M	M
Level 4 Interactive Courseware (ICW) - Real Time Participation	Y	Y	Y	Y	N	H	H
Intelligent Tutor [Serious Games]	Y	Y	Y	Y	N	H	H
Embedded Training Appended	Y	Y	N	Y	Y	M	M
Fully Embedded Training	Y	Y	N	Y	Y	M	M
Hypertext [Google]	N	Y	N	Y	Y	L	L
Hypermedia [You Tube]	Y	Y	Y	Y	N	H	H
Electronic Performance Support System (EPSS)	Y	Y	Y	Y	S	M	M
Audio Conferencing (with Handouts)	N	S	Y	Y	Y	L	L
Computer Conferencing	S	S	S	Y	Y	L	L
Video Tele-Conferencing	S	S	Y	Y	Y	L	L
Video Conferencing	S	S	Y	Y	Y	L	L
Internet Virtual Classroom [Virtual Learning Space]	S	S	S	Y	Y	L	L
Level 1 - Desk Top Trainer	Y	Y	Y	Y	N	H	H
Level 2 - Part Task Trainer (FTD: Levels 1 to 6)	Y	Y	Y	Y	N	H	H
Level 3 - Full Task Trainer (FFS: Level C)	Y	Y	Y	S	N	H	H
Level 4 - Full Task Trainer (FFS: Level D)	Y	Y	Y	S	N	H	H
Virtual Reality Level 1 - Augmented	Y	Y	Y	Y	N	H	H
Virtual Reality Level 2 - Partially Immersive	Y	Y	Y	Y	N	H	H
Virtual Reality Level 3 - Fully Immersive	Y	Y	Y	S	N	H	H

Display

Media	Support Drawings/Diagrams	Support Still Images	Support for Animation	Support Audio/Voice	Support Full Motion Video
Instructor-led Classroom	Y	Y	Y	Y	Y
Instructor-led On-location [On-the Job]	Y	Y	Y	Y	Y
Instructor with Computers [Electronic Mediated Classroom]	Y	Y	Y	Y	Y
Instructor with Equipment	Y	Y	Y	Y	Y
Print	Y	Y	N	N	N
Print with Computer	Y	Y	Y	Y	S
Print with Equipment	Y	Y	Y	Y	S
Audio Tapes [MP3] [iPod] (with Handouts)	S	S	N	Y	N
Video Tapes [DVD]	Y	Y	Y	Y	Y
Video Tapes [DVD] with Computers	Y	Y	Y	Y	Y
Video Tapes [DVD] with Equipment	Y	Y	Y	Y	Y
Level 1 Interactive Courseware (ICW) - Passive	Y	Y	N	S	S
Level 2 Interactive Courseware (ICW) - Limited Participation	Y	Y	S	S	S
Level 3 Interactive Courseware (ICW) - Complex Participation	Y	Y	Y	Y	Y
Level 4 Interactive Courseware (ICW) - Real Time Participation	Y	Y	Y	Y	Y
Intelligent Tutor [Serious Games]	Y	Y	Y	Y	Y
Embedded Training Appended	Y	Y	Y	Y	Y
Fully Embedded Training	Y	Y	Y	Y	Y
Hypertext [Google]	Y	Y	N	N	N
Hypermedia [You Tube]	Y	Y	Y	Y	Y
Electronic Performance Support System (EPSS)	Y	Y	Y	Y	Y
Audio Conferencing (with Handouts)	S	S	N	Y	N
Computer Conferencing	Y	Y	Y	Y	Y
Video Tele-Conferencing	Y	Y	Y	Y	Y
Video Conferencing	Y	Y	Y	Y	Y
Internet Virtual Classroom [Virtual Learning Space]	Y	Y	Y	Y	Y
Level 1 - Desk Top Trainer	Y	Y	Y	Y	Y
Level 2 - Part Task Trainer (FTD: Levels 1 to 6)	S	Y	Y	Y	Y
Level 3 - Full Task Trainer (FFS: Level C)	S	Y	Y	Y	Y
Level 4 - Full Task Trainer (FFS: Level D)	S	Y	Y	Y	Y
Virtual Reality Level 1 - Augmented	S	Y	Y	Y	Y
Virtual Reality Level 2 - Partially Immersive	S	Y	Y	Y	Y
Virtual Reality Level 3 - Fully Immersive	S	Y	Y	Y	Y

Fidelity

Media	Support/Emulate Tactile Cues	Support/Emulate Kinesthetic Cues	Equipment Display Fidelity: Level Supported	Equipment Control Fidelity: Level Supported	Equipment/Hardware Fidelity: Level Supported	Equipment Functional Fidelity: Level Supported	Equipment Motion Fidelity: Level Supported	Equipment Audio Fidelity: Level Supported	Equipment Visual Fidelity: Level Supported	Support/Emulate Performer Sense of Acceleration	Support/Emulate Performer Sense of Vibration	Support/Emulate Performer Sense of Pitch & Roll	Support Environment Simulation
Instructor-led Classroom	Y	Y	N	N	N	N	N	N	N	N	N	N	L
Instructor-led On-location [On-the Job]	Y	Y	N	N	N	N	N	N	N	N	N	N	M
Instructor with Computers [Electronic Mediated Classroom]	N	N	N	N	N	N	N	N	N	N	N	N	L
Instructor with Equipment	Y	Y	H	H	H	H	H	H	H	H	H	H	M
Print	N	N	N	N	N	N	N	N	N	N	N	N	N
Print with Computer	N	N	N	N	N	N	N	N	N	N	N	N	L
Print with Equipment	Y	Y	H	H	H	H	H	H	H	H	H	H	L
Audio Tapes [MP3] [iPod] (with Handouts)	N	N	N	N	N	N	N	M	N	N	N	N	N
Video Tapes [DVD]	N	S	N	N	N	N	N	M	L	N	N	N	N
Video Tapes [DVD] with Computers	N	N	N	N	N	N	N	M	L	N	N	N	L
Video Tapes [DVD] with Equipment	Y	Y	H	H	H	H	H	H	H	H	H	H	L
Level 1 Interactive Courseware (ICW) - Passive	N	N	L	L	L	L	N	L	L	N	N	N	N
Level 2 Interactive Courseware (ICW) - Limited Participation	N	N	L	L	L	L	N	L	L	N	N	N	N
Level 3 Interactive Courseware (ICW) - Complex Participation	N	S	L	L	L	L	L	M	L	N	N	N	N
Level 4 Interactive Courseware (ICW) - Real Time Participation	N	S	L	L	L	M	L	M	L	L	N	N	L
Intelligent Tutor [Serious Games]	N	S	L	L	L	M	L	M	L	L	N	N	L
Embedded Training Appended	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	L
Fully Embedded Training	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	L
Hypertext [Google]	N	N	N	N	N	N	N	N	N	N	N	N	N
Hypermedia [You Tube]	N	S	L	L	L	L	N	L	L	N	N	N	N
Electronic Performance Support System (EPSS)	N	N	L	L	L	L	N	L	L	N	N	N	L
Audio Conferencing (with Handouts)	N	N	N	N	N	N	N	N	N	N	N	N	N
Computer Conferencing	N	N	N	N	N	N	N	N	N	N	N	N	N
Video Tele-Conferencing	N	N	N	N	N	N	N	N	N	N	N	N	N
Video Conferencing	N	N	N	N	N	N	N	N	N	N	N	N	N
Internet Virtual Classroom [Virtual Learning Space]	N	N	N	N	N	N	N	N	N	N	N	N	N
Level 1 - Desk Top Trainer	S	S	L	L	L	M	H	M	M	M	L	N	M
Level 2 - Part Task Trainer (FTD: Levels 1 to 6)	Y	S	M	M	H	M	H	M	M	N	N	M	L
Level 3 - Full Task Trainer (FFS: Level C)	Y	Y	H	H	H	H	H	M	H	H	H	H	H
Level 4 - Full Task Trainer (FFS: Level D)	Y	Y	H	H	H	H	H	H	H	H	H	H	H
Virtual Reality Level 1 - Augmented	Y	Y	M	M	M	M	H	H	M	L	L	N	M
Virtual Reality Level 2 - Partially Immersive	Y	Y	M	M	M	M	H	H	M	L	L	N	M
Virtual Reality Level 3 - Fully Immersive	Y	Y	H	H	M	M	H	H	H	M	M	L	H

Activities

Media	Support Guided Discussions	Support Role Play	Support Teaming Exercises	Support Fine Motor Skills	Support Gross Motor Skills	Support Tracking Skills	Support Object Manipulation	Respond to Trainees Actions	Mitigate Personal Safety	Mitigate Safety of Others	Mitigate Environmental Safety	Mitigate Damage to Equipment/Data
Instructor-led Classroom	Y	Y	Y	Y	Y	N	N	N	N	N	N	N
Instructor-led On-location [On-the Job]	Y	Y	Y	Y	Y	N	N	N	N	N	N	N
Instructor with Computers [Electronic Mediated Classroom]	Y	Y	Y	Y	N	Y	N	Y	N	N	N	N
Instructor with Equipment	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N
Print	N	N	N	N	N	N	N	N	N	N	N	N
Print with Computer	N	N	N	Y	N	Y	N	Y	N	N	N	N
Print with Equipment	N	N	N	Y	Y	Y	Y	Y	N	N	N	N
Audio Tapes [MP3] [iPod] (with Handouts)	N	N	N	N	N	N	N	N	N	N	N	N
Video Tapes [DVD]	N	N	N	Y	Y	N	N	N	N	N	N	N
Video Tapes [DVD] with Computers	N	N	N	Y	N	Y	N	Y	N	N	N	N
Video Tapes [DVD] with Equipment	N	N	N	Y	Y	Y	Y	Y	N	N	N	N
Level 1 Interactive Courseware (ICW) - Passive	N	N	N	N	N	N	N	N	Y	Y	Y	Y
Level 2 Interactive Courseware (ICW) - Limited Participation	N	N	N	N	N	S	S	S	Y	Y	Y	Y
Level 3 Interactive Courseware (ICW) - Complex Participation	N	S	N	S	S	Y	Y	Y	Y	Y	Y	Y
Level 4 Interactive Courseware (ICW) - Real Time Participation	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Intelligent Tutor [Serious Games]	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Embedded Training Appended	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N
Fully Embedded Training	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N
Hypertext [Google]	N	N	N	N	N	N	N	N	Y	Y	Y	Y
Hypermedia [You Tube]	N	N	N	N	N	N	N	N	Y	Y	Y	Y
Electronic Performance Support System (EPSS)	N	S	N	Y	Y	S	S	Y	Y	Y	Y	Y
Audio Conferencing (with Handouts)	S	N	N	N	N	N	N	N	N	N	N	N
Computer Conferencing	S	S	S	N	N	S	S	N	N	N	N	N
Video Tele-Conferencing	S	S	S	S	S	N	S	N	N	N	N	N
Video Conferencing	Y	Y	S	S	S	N	S	N	N	N	N	N
Internet Virtual Classroom [Virtual Learning Space]	S	S	S	N	N	S	S	N	N	N	N	N
Level 1 - Desk Top Trainer	N	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y
Level 2 - Part Task Trainer (FTD: Levels 1 to 6)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Level 3 - Full Task Trainer (FFS: Level C)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Level 4 - Full Task Trainer (FFS: Level D)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Virtual Reality Level 1 - Augmented	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Virtual Reality Level 2 - Partially Immersive	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Virtual Reality Level 3 - Fully Immersive	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Evaluation & Feedback

Media	Support Feedback Immediate on Error	Support Feedback Immediate on Response	Support Post Session Feedback	Support Performance Evaluation	Support Knowledge/Comprehension Evaluation	Support Oral Presentations	Support Essay Writing	Support Group Projects	Support Collection of Scores	Support Collection of Feedback	Support Complex Questions Formulation	Support Complex Response Analysis
Instructor-led Classroom	Y	Y	Y	Y	Y	Y	Y	Y	S	S	Y	Y
Instructor-led On-location [On-the Job]	Y	Y	Y	Y	Y	Y	Y	Y	S	S	Y	Y
Instructor with Computers [Electronic Mediated Classroom]	Y	Y	Y	Y	Y	Y	Y	Y	S	S	Y	Y
Instructor with Equipment	Y	Y	Y	Y	Y	Y	Y	Y	S	S	Y	Y
Print	N	N	S	N	S	N	Y	N	S	S	Y	N
Print with Computer	N	N	S	N	S	N	Y	N	S	S	Y	N
Print with Equipment	N	N	S	N	S	N	Y	N	S	S	Y	N
Audio Tapes [MP3] [iPod] (with Handouts)	N	N	S	N	S	N	Y	N	S	S	Y	N
Video Tapes [DVD]	N	N	S	N	S	N	Y	N	S	S	Y	N
Video Tapes [DVD] with Computers	N	N	S	N	S	N	Y	N	S	S	Y	N
Video Tapes [DVD] with Equipment	N	N	S	N	S	N	Y	N	S	S	Y	N
Level 1 Interactive Courseware (ICW) - Passive	N	N	N	N	N	N	Y	N	N	N	N	N
Level 2 Interactive Courseware (ICW) - Limited Participation	S	S	S	N	S	N	Y	N	S	S	N	N
Level 3 Interactive Courseware (ICW) - Complex Participation	Y	Y	Y	N	Y	N	Y	N	Y	Y	Y	S
Level 4 Interactive Courseware (ICW) - Real Time Participation	Y	Y	Y	N	Y	N	Y	N	Y	Y	Y	Y
Intelligent Tutor [Serious Games]	Y	Y	Y	N	Y	N	Y	N	Y	Y	Y	Y
Embedded Training Appended	S	S	Y	N	S	N	Y	N	N	N	Y	N
Fully Embedded Training	S	S	Y	N	S	N	Y	N	N	N	Y	N
Hypertext [Google]	N	N	N	N	N	N	N	N	N	N	N	N
Hypermedia [You Tube]	N	N	N	N	N	N	N	N	N	N	N	N
Electronic Performance Support System (EPSS)	Y	Y	N	N	N	N	N	N	N	N	N	N
Audio Conferencing (with Handouts)	Y	Y	S	N	S	S	Y	S	S	S	N	N
Computer Conferencing	Y	Y	S	N	S	S	Y	S	S	S	Y	S
Video Tele-Conferencing	Y	Y	S	N	S	S	Y	S	S	S	Y	S
Video Conferencing	Y	Y	S	S	S	S	Y	S	S	S	Y	S
Internet Virtual Classroom [Virtual Learning Space]	Y	Y	S	N	S	S	Y	S	S	S	Y	S
Level 1 - Desk Top Trainer	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Level 2 - Part Task Trainer (FTD: Levels 1 to 6)	N	N	Y	Y	Y	Y	Y	Y	S	S	Y	Y
Level 3 - Full Task Trainer (FFS: Level C)	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Level 4 - Full Task Trainer (FFS: Level D)	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Virtual Reality Level 1 - Augmented	N	N	Y	Y	Y	Y	Y	Y	S	S	Y	Y
Virtual Reality Level 2 - Partially Immersive	N	N	Y	Y	Y	Y	Y	Y	S	S	Y	Y
Virtual Reality Level 3 - Fully Immersive	N	N	Y	Y	Y	Y	Y	Y	S	S	Y	Y

Appendix 4: Accepted Requirements

No	Capability	Raw Requirement and other notes	Formed Requirements	ID
1	To input training objectives	The system should have as input the training objectives	Should use as input the TOs.	2
2	To help determining the training solution	The system should help determining the training solution	Should help at determining training solutions.	5
3	To specify media training device/asset needed to train a training objective	The system should specify which device is needed to train a training objective	Should specify training media devices needed to train a TO.	9
4	To include database/catalogue of training objectives	The system should include a catalogue of the training objectives split according to their characteristics	Should provide a catalogue of TOs.	2.1
5	To split training objective depending upon their characteristics		TOs should be split according to their characteristics.	2.2
6	To include also physical characteristics of training objectives	The training objective characteristics - include physical characteristics (e.g. how many degrees of visual field is needed) – physical properties required by the exercise	Should specify the physical characteristics of TOs.	2.2.1
7	To select training objectives from catalogue	Select training objective (input) from catalogue (data-base)	TOs should be selected from a database.	2.3
8	The training objectives data-base to be updatable	The training objectives catalogue should be able to be updated	TOs database should be updatable.	20
9	To match training media characteristics with	The system should match training media	Should match training media characteristics	12

	training objectives characteristics	characteristics (attributes) with training objectives characteristics (attributes)	with TOs characteristics.	
10	To associate the device capabilities with the training objectives	The devices capabilities to be associated with the training objectives	Should associate the training devices capabilities with TOs.	12.1
11	To have shared language on media characteristics	Shared language on media attributes	Training media characteristics should share the same language.	11.1.2
12	To connect training objectives with the technology	Show the/and link training objectives with technology (use common language)	Should connect TOs with training technology.	12.2
13	To measure the effectiveness and efficiency of training	The system should have training effectiveness and efficiency measures introduced	Should measure the training effectiveness and efficiency.	13
14	To show the training value	Include training value	Should indicate the training value of training media devices.	58
15	To indicate learning value using R. Gagne's learning taxonomy	Use Robert Gagne's taxonomy of learning	Should indicate the training value using Gagne's categories of learning outcomes.	145
16	To specify training media blend for a training exercise	The system should specify what kind of blend of media is needed to do a training exercise	Should specify training media blend for a training exercise.	15
17	To be used during training design phase	The system should be used during training design phase	Should aid the training design phase.	16
18	To support TNA	Tool should support TNA	Should support TNA.	43
19	To connect training requirements generation (part of TNA) and	Tool to act as interface between training requirement part of TNA	Should connect the training requirements (TNA output) with the	108

	training environment development	and training environment development process	training environment development process.	
20	To indicate the training environment complexity level needed	Indicate training environment complexity level needed	Should indicate the training environment complexity level.	22
21	To assess training media	Needs to assess training media	Should assess training media.	26
22	To specify training media options	The tool should generate (output) training media options	Should provide training media options.	30
23	To show weightings of training media options	Have weightings on training media options (possibilities) - output	Should include training media weightings.	60
24	To describe options	Provide description of options	Should provide description of training media options.	31
25	To give information about training devices	The description of options should contain information about training devices, training media and about things to be trained	Should contain information about the training devices.	34.1
26	To give information about training media		Should contain information about training media.	34.2
27	To give information about knowledge and skills to be trained		Should contain information about knowledge and skills to be trained.	34.3
28	To define the devices needed	The device specification should include information about number of devices and definition of devices	Should provide definitions of training devices.	34.1.2
29	To show interoperability information on training equipment	Include interoperability characteristics of training equipment	Should provide interoperability information.	34.1.4

30	To have definition of training media needed	The media specification should include information about definitions and characteristics of media	Should provide definitions of media.	34.2.1
31	To specify the training media characteristics needed		Should specify needed training media characteristics.	34.2.2
32	To connect or include training assets capabilities register	Have capability register (catalogue) for the training assets (Dave Calmus; * the breakdown is important)	Should provide training media devices capability register (catalogue).	66
33	To update training device capability register	Training devices register may need modification (adds on) possibility	Training devices capability register should be updatable.	9.1
34	To have appropriate specification of devices characteristics	Specify devices capabilities characteristics in sufficient detail	The capability register should contain characteristics of devices.	66.1
35	To provide capabilities/functionalities elements needed	Provide a library of capabilities/functionalities elements needed	Should provide capabilities/functionality needed for training media devices.	110
36	To have media assets broke down in in functionalities	Breakdown of media, assets, etc. based on functionality	Training media devices should be broken down based on their functionalities.	111
37	To have catalogue of functionalities	Have library, terminology, types for functionalities	Should have a library of training media devices functionalities.	117
38	To output a summary of training media capabilities	Output summary of training media capabilities	Should provide summary of training media capabilities.	128
39	To define the training media capabilities	Define capabilities as much as you can	Training media capabilities should be defined.	128.1

40	To trace tool outcome	Show traceability of tool's decisions	Should trace the decisions made.	36
41	To document changes made within the tool	Document the changes made within too	Should document any changes made.	47
42	To document who does changes within the tool	The changes should be documented in terms of who did the change	Should document who did the changes.	47.1
43	To document what change was done within the tool	The changes should be documented in terms of when was the change made	Should document when a change was done.	47.2
44	To document what change was done within the tool	The changes should be documented in terms of what the change was	Should document what change was done.	47.3
45	To allow modification only by central	The changes made should be done only by central not by front users (updates to come to a single point)	Should allow changes done only by 'central'.	90
46	To not have duplicated information	No duplication of information	Should not duplicate information.	89.2
47	To have open architecture	Have open architecture	Should have open architecture.	92
48	To have modular and generic architecture	Have modular and generic architecture	Should have modular and generic architecture.	160
49	To store the outputs	Store the answers	Should store the outputs.	142
50	To perform trade-off analysis between training media options give the training task	Trade-off analysis between training media options (*solutions) given the task	Should perform trade-off analysis between training media options given the training tasks.	168
51	To have safety specifications	Include safety specifications	Should provide information about training device safety.	169

52	To take into consideration IP rights and ownership	Take into account ownership/IP	Should consider ownership and IP rights of training media devices.	170
53	To have single domain user	Do nor accommodate for different people	Should have a single domain user.	148
54	To specify capability/functionality needed for training media device system	Specify capability/functionality	Should specify the capability/functionality required for the training media devices.	110.1
55	To lock down the output	(Output) not to allow twitching	Should lock down the output.	53
56	To provide training media device options	Provide options rather than answers	Should provide training media options.	174
57	To include training devices manufacturer specifications	Include manufacturer device specification	Should provide training' devices manufacturer's information.	175
58	To help at making quicker decision making (on training media device selection)	Tool to help make quicker decision making	Should aid decision-making.	176
59	To have consistency	Have consistency, lock down for standardisation	Should be consistent and locked down for standardisation.	177
60	To have black box	Black box if needed - for interaction with various system architecture, standards and protocols	Should have black bocks.	178
61	To not duplicate existing processes	Not to duplicate existing processes	Should not duplicate existing processes.	179
62	To generate list of possible media options	Tool to generate a list of possible(s) from the media options	Should generate list of possible media options.	180
63	To specify component elements rather that specific end systems	Tool to specify elements (components) rather than specific end systems	Should specify training media components	181

			rather than training media systems.	
64	To connect but not assess media based on schedule, cost, availability.	Take out the constrains on media assessments (for suitability) based on schedule, cost, availability (for this to connect with other tools) to just suggest the best media option	Should not assess media based on: schedule, cost, availability.	183
65	To allow for future exploitation in other business areas	Allow possibility to be exploit, to be developed in different business areas	Should allow for development in other business areas.	184
66	To be updatable as technology develops	Capability to being updated as technology evolves	Should be updatable.	185
67	To be linkable with other systems	To be linkable	Should be able to be linked with other systems.	187
68	To work well for what is intended before expansion	Not to have more than can handle (know the core capability), be focused and not expand until is not working for what is intended	Should not be expanded until is not working for what is basically intended.	188
69	To generate information on device integration (and/or interoperability)	To generate training device integration requirement (technical and other)	Should provide information on training media devices' integration.	189
70	To have open architecture	Keep things open	Should be an open system.	191
71	To be build to be distributive	Build to be distributed from day one	Should be built to be distributive.	192
72	To have XML structure	XML structure	Should have XML structure.	193

Appendix 5: Information requested from stakeholders and typical questions.

Primary:

- Short description of role and activity.
- What properties do you want a decision-making support system to have?
- What features you will find most useful?
- What features you will find less useful?
- Specifications of how the system should work.
- Interface specifications.
- How the system should do its work?
- How the interfaces should look and behave?
- System performance requirements.
- What functions the system should have?
- Technical aspects that the tool should have.

- Short description of each requirement
- Rational of given a requirement

Secondary:

- Information in regards with:
    - Training resources
    - Performance evaluation
    - Existing processes
    - Existing tools

Appendix 6: Ethical considerations

- **Additional information for stakeholders**

This interview/workshop is conducted to support my PhD research by collecting the stakeholder's requirements […].

The project and this interview/workshop are conducted at the **UNCLASIFIED** level.

The information collected will be used only to support this research and is subject to the Loughborough University / BAE Systems Strategic Alliance Agreement (ref. no. AT2121 / 2N1198).

Luminita Ciocoiu

Appendix 7: LVC definitions

Reference	Area	Definition
Van der Pal, J., Keuning, M. and Lemmers, A. (2011). A Comprehensive Perspective on Training: Live, Virtual and Constructive, , RTO-MSG-MP-087, 13-1 – 13-9, NATO.	Training technology	**Live -** training involving real people operating simulated systems. For example a pilot operating a real jet. **Virtual** - training involving real people operating simulated systems. For example a pilot operating a simulated jet. **Constructive** - training involving simulated people operated simulated systems. Real people may simulate these simulations, but are not directly involved in determining the outcome. By themselves these simulations are often used to train decision making at high levels of command. Connected with Virtual or Live training assets, constructive forces form the basis of training scenarios, providing friendly, neutral, and opposing forces.
Kirby, B., Fletcher, G. and Dudfield, H. (2011). Live Virtual Constructive Training Blend Optimisation Study, RTO-MSG-MP-087, 18-1 – 18-10, NATO.	Training domains	**Live** - Real person in a real-world platform. **Virtual -** Real person in a virtual platform (simulator, role-player station). **Constructive -** Computer Generated Forces – could be fully autonomous or under control of role-player.
Pike, J. and Huddlestone, J. (2011). Training Needs Analysis for Team and Collective Training. BAE Systems, HFI Defence Technology Centre Report. HFIDTCPIII_T13_01.	Training Environments	**Virtual simulation** - real people operating simulated equipment in a virtual environment. **Constructive simulation** - real people exercising military decisions on the basis of information constructed by a computer system. **Live simulation** - real people operating real equipment with simulated effects in a live environment. **Embedded simulation** - the incorporating of simulation capability into operational

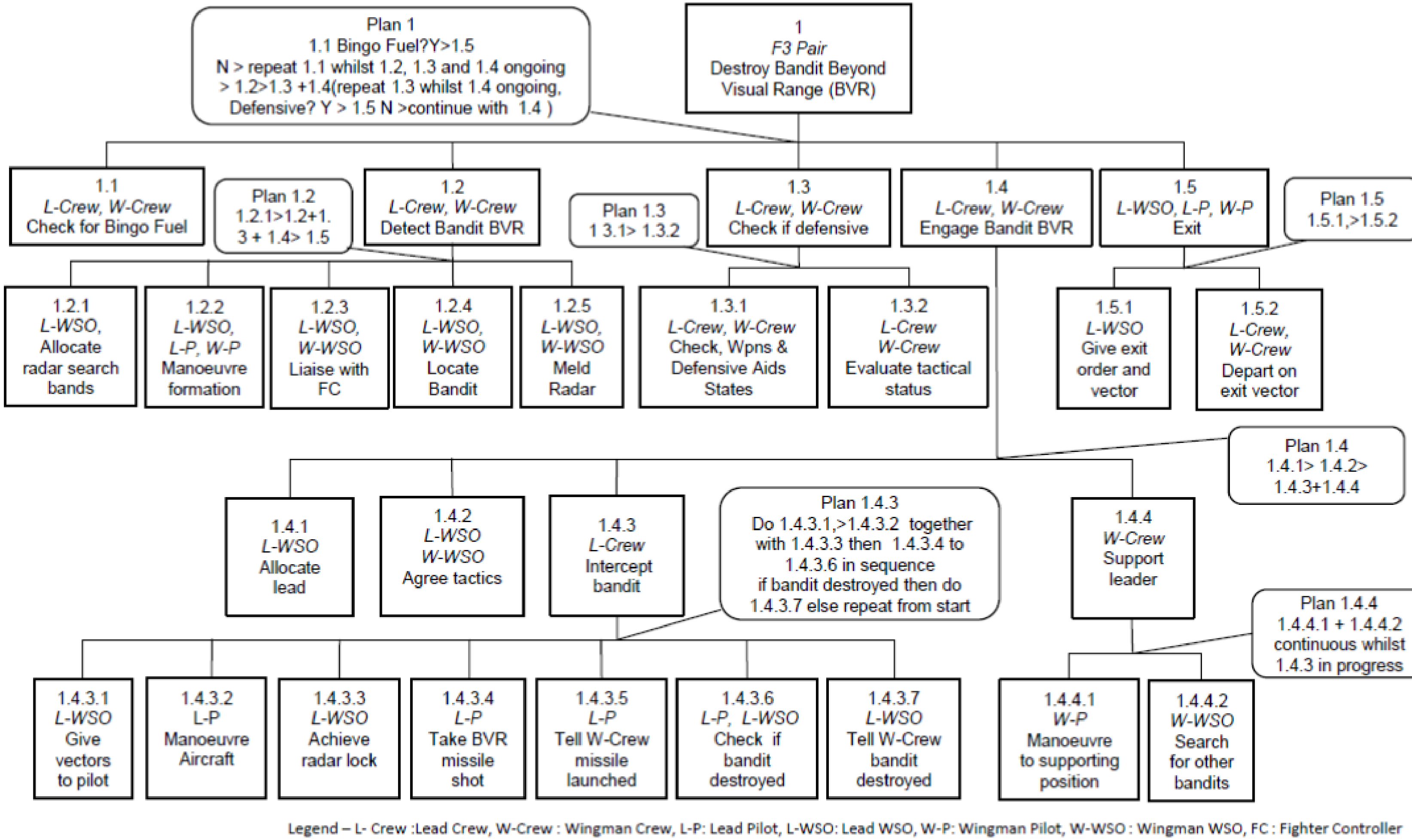
		equipment. Simulation models build into warfare systems would fall into this category. **Networked simulation** - the networking together of multiple simulators. **Distributed simulation** - the networking of simulators and simulator networks across different sites. **Synthetic wrap** - the combination of the use of live and virtual simulation to provide and extended battlespace for training. This enables Operational pictures to be populated with elements that are outside the geographical area being used for training. The challenge is transitioning an element traversing the constructive space into the live space. **Augmented reality** - the technique of integrating synthetic elements into the live environment.

Appendix 8: Tornado F3 Pairs Training Example (Pike and Huddlestone, 2011)

Tornado F3 Pairs Training Example

"The use of a coordinated pair of mutually supporting aircraft has been central to fighter tactics since WW1. The example used as a case study running through the three analysis phases is based on the requirement to provide enhanced training in pairs tactics for Tornado F3 pilots and Weapons Systems Operators (WSOs) in training. The detail is derived from research data from a transfer of training trial conducted to establish the effectiveness of a networked desktop computer system for training pairs tactics. This example has been chosen as it is a highly demanding task which places extreme demands on the teamwork skills of the crews. The context is a pair of fighters patrolling an area of airspace searching for bandit fighters or bombers. The pair consists of a lead aircraft and a wingman aircraft. The lead aircraft controls the intercept. The search is conducted by the WSOs using the air to air radars. The search space is divided between them to improve the efficiency of the search. A ground based or airborne Fighter Controller if present can also give vectors to a bandit aircraft. If bandits are detected and the pair have a tactical advantage an intercept ensues. As the WSOs are looking at different sectors of airspace, the WSO who has detected the bandit has to give directions to the other WSO so that he can get the same radar picture. This is referred to as the radar meld. The aim of the pair is initially to destroy the bandits Beyond Visual Range (BVR) with radar guided missiles. If there is a single bandit, the leader will engage it whilst the wingman flies in support ready to take a back up shot if required. If there are two bandits, then both aircraft will engage a bandit after agreeing who is going to attack which one. The WSOs direct the radar based intercept. If the BVR intercept is unsuccessful but the pair still have a tactical advantage a visual intercept ensues. The WSO "talks the pilot's eyes" onto the bandit location during the merge into the visual. Once the pilot can see the bandit he takes over the intercept aiming to shoot the bandit down with heat-seeking missiles. During the visual intercept the WSOs provide an extra pair of eyes to watch for threats at visual range."

Appendix 9: HTA example (Pike and Huddlestone, 2011)



Appendix 10: Task and Role Matrix example – Pike and Huddlestone (2011)

Task List	Roles Participating			
	Lead-Crew		Wingman-Crew	
	L-P	L-WSO	W-P	W-WSO
1.1 Check for Bingo Fuel	X	X	X	X
1.2 Detect Bandit BVR	X	X	X	X
1.2.1 Allocate radar search bands		X		
1.2.2 Manoeuvre formation	X	X	X	
1.2.3 Liaise with Fighter Controller		X		X
1.2.4 Locate bandit		X		X
1.2.5 Meld radar		X		X
1.3 Check if Defensive	X	X	X	X
1.3.1 Check wpns and defensive aids states	X	X	X	X
1.3.2 Evaluate tactical status	X	X	X	X
1.4 Engage Bandit BVR	X	X	X	X
1.4.1 Allocate lead		X		
1.4.2 Agree tactics		X		X
1.4.3 Intercept bandit	X	X		
1.4.3.1 Give vectors to pilot		X		
Etc.…				

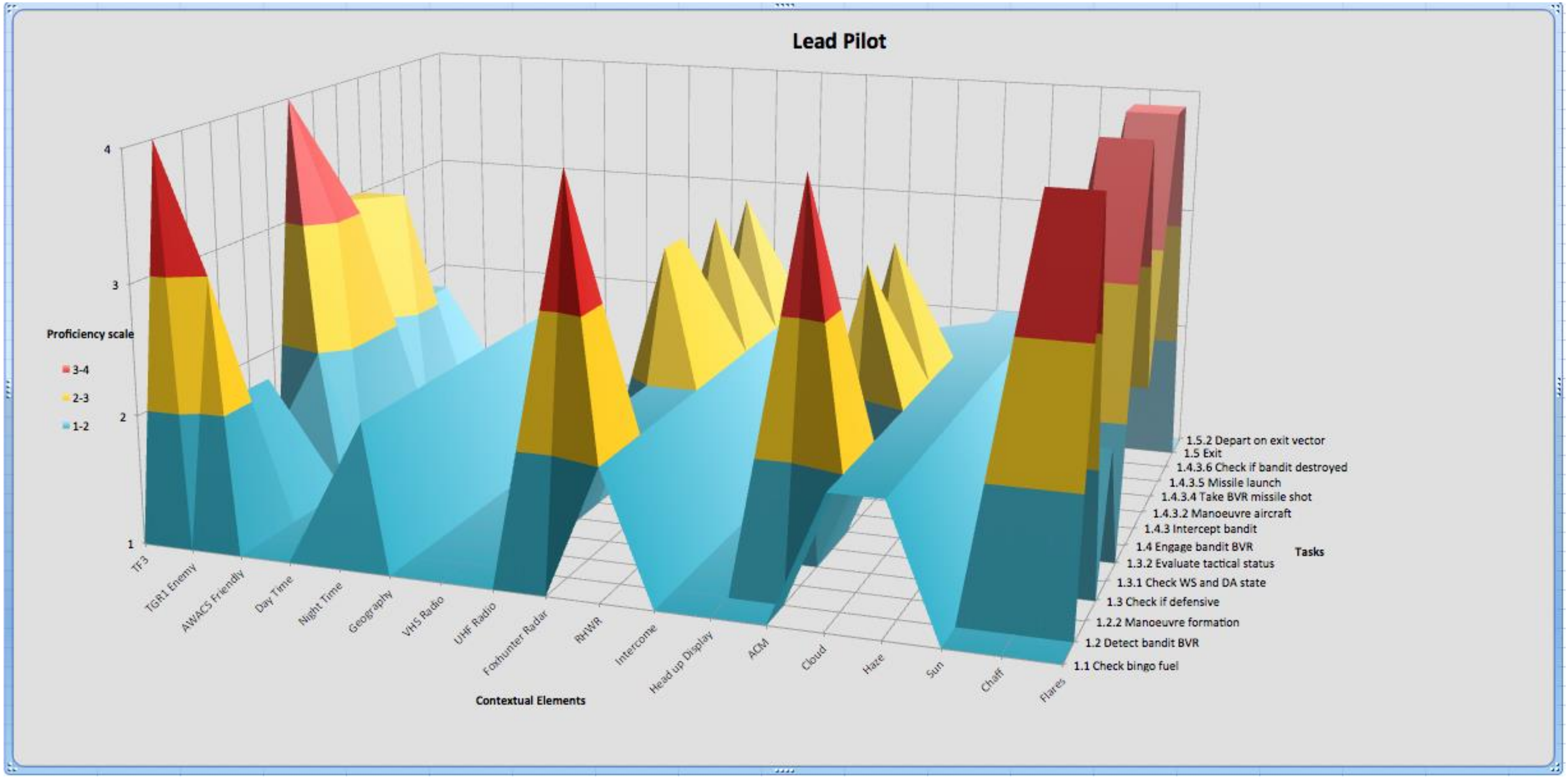
Appendix 11: Additional information about the TNAs used in the two case studies

Case Study 1	Case Study 2
The requirement for this work originated in a request from the Royal Navy for the development of a methodological approach for the conduct of Training Needs Analysis (TNA) which could be applied in a set of TNAs to be conducted for collective training […]. […] the method developed is referred to as Team/Collective TNA (TCTNA) […] *(and)* is applicable to both team and collective training however they may be defined. The TCTNA guidance provided […] is designed to extend and amplify the extant guidance on the TNA provided in the JSP822, not to replace it. […] The TCTNA method that has been devised is structured around an adaptation of the TNA Triangle model devised in a previous phase of HFI DTC research (HFI DTC, 2009). It is composed of five components: Constraints analysis, Team/Collective Task Analysis, Training Overlay Analysis, Training Environment Analysis and Training Option(s) Selection. […] Worked examples and templates are provided for the components of each stage of the methodology. It is anticipated that this guidance will be used by military and commercial TNA specialists […]. […] A Tornado F3 Pairs training example is used to illustrate various elements of the analysis phases. (Extract from the Pike and Huddlestone study)	The TNA report presents the […] aircrew training specialists' recommendations for the modernised Basic […] Pilot Training System [...] to be conducted on the T-21 aircraft […]. The TNA techniques employed were compliant with […] UK Ministry of Defence (MoD) procedures […] and provide an auditable trail from individual training tasks through the Training Objectives (TO) that will be used to facilitate the subsequent training course design. A Media Matching Analysis (MMA) was conducted to match the TO to the most suitable training media specified under the T-21 Aircraft Acquisition and Ground-Based Training Environment (GBTE) programmes. […] *(The)* current […] *(Training)* System is governed by a series of 5 years plans […]. Therefore, all future […] aircrew training system modules will be required to fit in to the same duration windows […]. The TNA assumes the agreed […] *(previous)* Phase 1 exit standard […] and takes no account of a potential new […] Primary Training platform. […] A Training Task List (TTL) was derived which includes all the tasks to be trained during the modernised […] Pilot flying syllabus (Phase 2 through 4). […] The remaining tasks within the TTL were divided into Basic flying tasks ([…] Phases 2 & 3) and Advanced flying tasks ([…] Phase 4). This TNA analyses the Basic flying tasks only; the Advanced flying tasks are the subject of further TNA. (Extract from the Customer report)

Appendix 12: List of TNA documents from were data used in the case studies was extracted

TCPP input	Case Study 1	Case Study 2
Trainees roles	• Role Definition Table • Role Matrix	• All
Trainees numbers	N/A	N/A
Task to be performed	• HTA (TCT) Diagram • Task and Role Matrix	• Training and Enabling Objectives Consolidated list
Context specific elements	• Generic Scenario Table • External Context Interaction Table • Environmental Description Interaction table • Role Definition Table • System Matrix • Communications Diagram • Communications Matrix	• Conditions and Standards
Information about trainees past experience	N/A	• Training Gap Statement
Proficiency scale	N/A	• Training Gap Statement

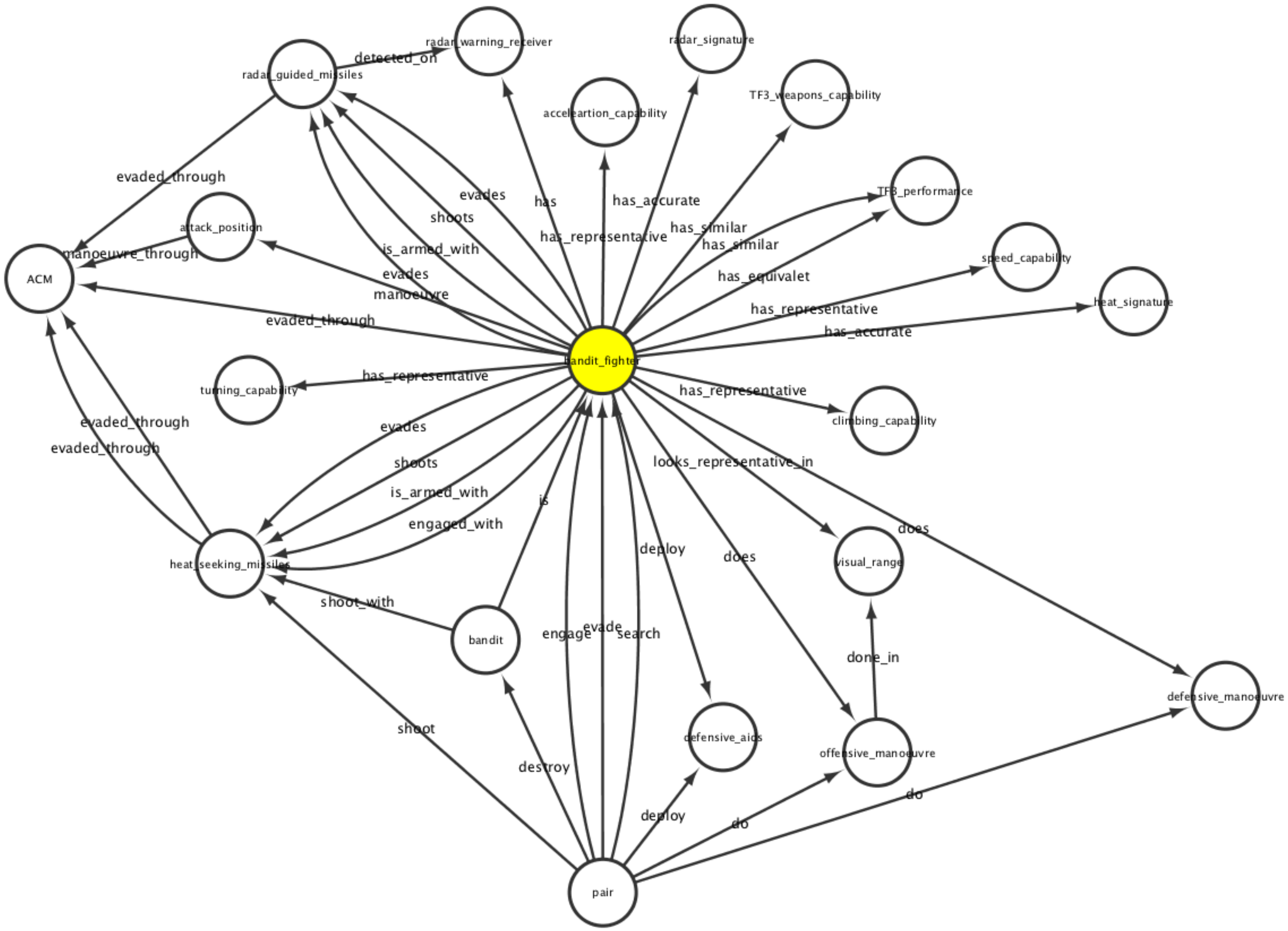
Appendix 13: Output of TCPP analysis for Lead Pilot (Case Study 1)



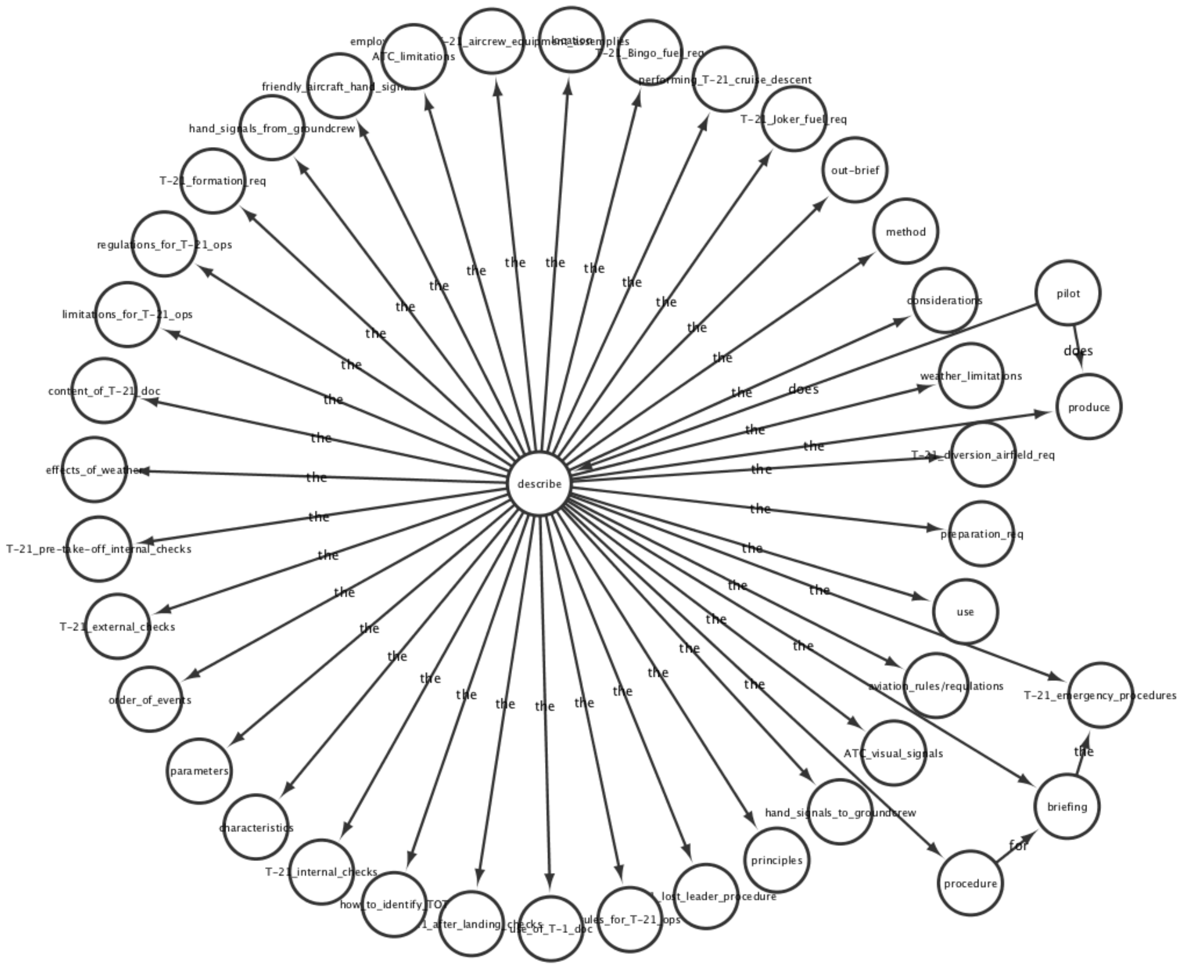
Appendix 14: Feedback Form (TCPP and ToA demo)

Functionality	Compliance with Requirements
General Appearance	Ease of use
Other features that need to be added (in relation with what already exist in the tool)	Anything else missing

Appendix 15: Example of requirement component and its neighbours (ToA analysis)



Appendix 16: Example of requirement's component (Case Study 2)



Appendix 17: List of Requirement's components and their associated Attributes

Requirement's component	Attributes
aircraft_limitations	
	assess (the)
	given_eq
	given_info
	ground
	i_freq
	n_diff
	s5
	(on) sortie/flight
	v_imp
aircraft_sign-out_procedure	
	perform (the)
	(in) F700
	given_info
	given_eq
	ground
	s5
	n_diff
	v_imp
	i_freq
airfield_details	
	briefing (for)
	given_info
	given_eq
	ground
	s6
	s7
	n_diff
	m_imp
	v_freq
airfield_limitations	
	identify (the)
	given_info
	given_eq
	ground
	s2
	s5
	n_diff
	v_imp
	m_freq
airspace_booking	
	submit (the)
	given_info
	given_eq
	ground
	s5
	n_diff
	m_imp
	v_freq
airspace_requiremen ts	
	extract (the)
	interpret (the)
	plan (the)
	given_info
	given_eq
	s2
	s5
	s6
	s7
	m_diff
	v_imp
	v_freq
airspace_restrictions	
	extract (the)
	interpret (the)
	s2
	s5
	m_diff
	v_imp
	v_freq
alternate_sortie	
	briefing (for)
	given_info
	given_eq
	ground
	s6
	s7
	n_diff

	m_imp
	m_freq
apply	
	pilot (does)
	(the) details_from_T-21_doc
	(the) limitations_for_T-21_ops
	(the) requlations_for_T-21_ops
	(the) rules_for_T-21_ops
	(the) individual_formation_req
assess	
	pilot (does)
	(the) aircraft_limitations
	(the) effects_of_weather
	(the) ATC_limitations
	(the) impact_of_late_warnings/NOTAMs
assessing_Intel_sc	
	principles (for)
	given_info
	given_eq
	ground
	n_diff
	m_imp
	m_freq
Bingo_fuels	
	calculate (the)
	given_info
	given_eq
	ground
	s2
	s5
	s7
	n_diff
	v_imp
	v_freq
briefing	
	describe (the)
	procedure (for)

	perform (the)
	(the) sortie_content
	(the) sortie_weather
	(the) alternate_sortie
	(the) T-21_emergency_procedures
	(the) airfield_details
	(for) time_hack
	(the) sortie_comms
	(the) sortie_formation
	s6
	s7
	n_diff
	m_imp
	v_freq
calculate	
	pilot (does)
	(the) T-21_take-off_data
	(the) T-21_landing_data
	(the) Joker_fuels
	(the) Bingo_fuels
	(the) en-route_safety_altitude
calculate_en-route_safety_altitude	
	method (for)
	given_info
	given_eq
	ground
	m_diff
	v_imp
	v_freq
	s5
calculate_T-21_landing_data	
	method (for)
	given_info
	given_eq
	ground
	s5
	n_diff
	v_imp

	m_freq
calculate_T-21_take-off_data	
	method (for)
	given_info
	given_eq
	ground
	n_diff
	v_imp
	m_freq
characteristics	
	describe (the)
	(for) T-21_sortie
checking_aircraft_limitations	
	procedure (for)
	(in) F700
	given_info
	given_eq
	ground
	s5
	n_diff
	v_freq
	i_freq
comms_plan	
	establish (the)
	given_info
	given_eq
	ground
	s2
	s6
	s7
	n_diff
	m_imp
	m_freq
conduct_debrief	
	procedure (for)
	given_info
	given_eq
	ground
	s6
	s7
	m_diff
	v_imp
	v_freq

conduct_in-brief	
	procedure (for)
	given_info
	given_eq
	ground
	s6
	s7
	n_diff
	m_diff
	v_freq
conduct_SE_Fitter_debrief	
	procedure (for)
	given_info
	given_eq
	ground
	s6
	s7
	n_diff
	m_imp
	i_freq
confirmation_check	
	perform (the)
	(for) select_aircraft_suitability
	given_info
	given_eq
	s2
	s6
	n_diff
	m_imp
	m_freq
content_of_T-21_document	
	describe (the)
	given_info
	given_eq
	ground
	s2
	s5
	m_diff
	v_imp
	v_freq
create	
	pilot (does)

	(the) flight/mission_plan
	(the) take-off_timing
	(the) taxi_timing
create_flight/mission _fuel_plan	
	method (for)
	considerations (for)
	given_info
	given_eq
	ground
	s2
	s5
	s6
	s7
	n_diff
	v_imp
	v_freq
create_take-off_timing	
	method (for)
	given_info
	given_eq
	ground
	s2
	s7
	n_diff
	v_imp
	m_freq
create_taxi_timing	
	method (for)
	given_info
	given_eq
	ground
	s2
	s7
	n_diff
	v_imp
	m_freq
describe	
	pilot (does)
	(the) method
	(the) limitations_for_T-21_ops
	(the) rules_for_T-21_ops

	(the) effects_of_weather
	(the) requlations_for_T-21_ops
	(the) use_of_T-21_doc
	(the) content_of_T-21_doc
	(the) ATC_limitations
	(the) T-21_Bingo_fuel_req
	(the) T-21_Joker_fuel_req
	(the) how_to _iudentify_TOT
	(the) principles
	(the) considerations
	(the) T-21_diversion_airfield_req
	(the) characteristics
	(the) T-21_formation_req
	(the)T-21_emergency_procedures
	(the) briefing
	(the) weather_limitations
	(the) procedures
	(the) out-brief
details_from_T-21_doc	
	extract (the)
	interpret (the)
	apply (the)
	given_info
	given_eq
	ground
	s2
	s5
	m_diff
	v_imp
	v_freq
diversion_airfields	
	identify (the)
	given_info
	given_eq

	ground
	s2
	s5
	n_diff
	m_imp
	m_freq
diversions	
	plan (for)
	given_info
	given_eq
	ground
	air
	day
	night
	VMC
	IMC
	s2
	s6
	s7
	n_diff
	v_imp
	m_freq
effects_of_weather	
	describe (the)
	assess (the)
	plan (for)
	(on) T-21_flights/mission
	given_info
	given_eq
	ground
	s2
	s5
	m_diff
	v_imp
	v_freq
en-route_safety_altidtude	
	calculate (the)
	given_info
	given_eq
	ground
	s5
	m_diff
	v_imp
	v_freq
engineering_debrief	
	perform (the)
	procedure (for)
	given_info
	given_eq
	ground
	s6
	s7
	m_diff
	v_imp
	v_freq
ensure	
	pilot (does)
	(the) sortie_authorisation
establish	
	pilot (does)
	(the) revisionary_plan
	(the) plan_for_loss_of_supp_assets
	(the) reduced_no_plan
	(the) comms_plan
	(the) poor_weather_plan
	(the)revisionary_altex
establish_plan_for_loss_of_T-21_supp_assets	
	method (for)
	given_info
	given_eq
	ground
	s2
	s6
	s7
	n_diff
	m_imp
	m_imp
establish_T-21_altex	
	method (for)
	given_info
	given_eq
	ground

	s2
	s6
	s7
	n_diff
	m_imp
	m_imp
establish_T-21_comms_plan	
	method (for)
	given_info
	given_eq
	ground
	s2
	s6
	s7
	n_diff
	m_imp
	m_imp
establish_T-21_departure_plan	
	method (for)
	given_info
	given_eq
	ground
	s2
	s5
	n_diff
	v_imp
	m_freq
establish_T-21_recovery_plan	
	method (for)
	given_info
	given_eq
	ground
	s2
	s5
	n_diff
	v_imp
	m_freq
establish_T-21_reduce_no_plan	
	method (for)
	given_info
	given_eq
	ground
	s2

	s6
	s7
	n_diff
	m_imp
	m_freq
establisg_T-21_revisionary_plan	
	method (for)
	given_info
	given_eq
	ground
	s2
	s6
	s7
	n_diff
	m_imp
	m_freq
evaluate	
	pilot (does)
	(the) support_asstes
	(the) potential_co-operative_assets
extract	
	pilot (does)
	(the) airspace_restrictions
	(the) airspace_req
	(the) details_from_T-21_doc
F700	
	checking_aircraft_limitations (in)
	aircraft_sign-out_procedure (in)
flight_plan	
	submit (the)
	given_info
	given_eq
	ground
	s5
	n_diff
	m_imp
	v_freq
flight/mission_plan	
	create (the)
	given_info

	given_eq
	ground
	s2
	s5
	s6
	s7
	n_diff
	v_imp
	v_freq
go-no-go_criteria	
	identify (the)
	given_info
	given_eq
	ground
	s2
	s5
	n_diff
	v_imp
	m_freq
handling_emergencies	
	plan (for)
	given_info
	given_eq
	ground
	s2
	s5
	s7
	n_diff
	m_imp
	m_freq
how_to_identify_TOT	
	describe (the)
	given_info
	given_eq
	ground
	s2
	s5
	n_diff
	v_imp
	m_freq
i_freq	
	aircraft_sign-out_procedure
	weather_limitations
	conduct_SE_Fitter_debrief
	produce_mission_plan_output
	checking_aircraft_limitations
	poor_weather_plan
	signing_for_the_aircraft
	aircraft_limitations
	manually_planning_route
	manually_planning_timing
identify	
	pilot (does)
	(the) TOT
	(the) sortie_objectives
	(the) airfield_limitations
	(the) potential_co-operative_assets
	(the) support_asstes
	(the) go-no-go_criteria
	(the) Rules_of_Engagement
	(the) weather_effects
	(the) target_DPI
	(the) diversion_airfields
	(the) Intel_sc

Appendix 18: DMSS Evaluation - Survey

DMSS Evaluation – Survey

This survey is conducted to support my PhD research by gathering SME's feedback on the development of the Decision Making Support System (DMSS).

The information collected will be used only to support this research and it is subject to the Loughborough University / BAE Systems Strategic Alliance Agreement (ref. no. AT2121 / 2N1198).

Participants should not feel obliged to answer all the questions in the survey. Furthermore, the participants identity and answers will not be revealed to unauthorised personnel or made available to the public domain.

The completed surveys should be sent to Luminita Ciocoiu (L.Ciocoiu@lboro.ac.uk) or to the designated person of contact in the organisation.

A. Please state your:

   Name ___

   Function/Position ___

   Job responsibilities (in brief) __

   E-mail (if you agree to be contacted for follow up or clarification reasons) __

B. Please tick (or underline) one answer in relation to the following statements:

   1. The report is clear and understandable

      ☐ Strongly agree

      ☐ Agree

      ☐ Neither agree nor disagree

      ☐ Disagree

      ☐ Strongly disagree

   2. The report has provided sufficient relevant information (given the context)

      ☐ Strongly agree

      ☐ Agree

☐ Neither agree nor disagree

☐ Disagree

☐ Strongly disagree

C. These questions asks for your opinion about the DMSS compliance with requirements solicited at BAE Systems. Please rank the following with 1-not at all; 2-in part; 3-almost completely; 4-completely

- How well does the system <u>address</u> the following requirements?
    1. Uses existing information as input (TNAs, pilot assessment information) __
    2. Acts as an interface between TNA and Design __
    3. Provides feedback to TNA __
    4. Helps in analyses of requirements __
    5. Derive functionality based on requirements __
    6. Link with training tasks __
    7. Assess complexity of task __
    8. To be tailored on pilot performance results __
    9. Link with records of pilots __
    10. Captures pilot characteristics __
    11. Tailored for individuals __
    12. Utilises key components of learning activity __
    13. Provides relevant information that needs to be transmitted __
    14. Follows instructional design process __
    15. Provides relevant output to be used in Design (Training and Training Media Design) __
    16. Provides relevant output to be used in Analysis phase of Design __
    17. Improves the functional analysis process __
    18. Output to be visual __
    19. Output to Excel __

- How well the main functionality of the system <u>supports (has considerations for)</u> the following requirements? (The system as a whole supports these requirements but they are not met directly by the DMSS)
    1. High-level taxonomy of training requirements __

2. Entry and exit standards for pilots __
3. Link learning tasks with media attributes __
4. Categories of courses __
5. Distinguish between media and method __
6. Link methods with media __
7. Methodology to assess capability __
8. Options to add new assets __
9. Link training requirements with media options __
10. Component elements of media __
11. Blend of media __
12. Training media devices integration requirements __
13. To drive scenario __

D. Please rate with 1-almost none; 2-some effects; 3-big effect; 4-transformational effect, the following DMSS system components on their capabilities.

- Trainee Contextual Proficiency Profile (TCPP)
  1. Functionality (How useful it is?) __
  2. Usability (What it is the likelihood of the TCPP being used?) __
  3. Value
     3.1 Work time benefits __
     3.2 Work quantity benefits __
     3.3 Work quality benefits __
     3.4 Cost benefits __
  4. Do you expect the TCPP to have an impact (change the way of doing things) __

- TNA output Analysis
  1. Functionality (How useful it is?) __
  2. Usability (What it is the likelihood of TNA output Analysis being used?) __
  3. Value
     3.1 Work time benefits __
     3.2 Work quantity benefits __
     3.3 Work quality benefits __
     3.4 Cost benefits __

4. Do you expect the TNA output Analysis to have an impact (change the way of doing things) __

- Architecture of Instructional Process

1. Functionality (How useful it is?) __
2. Usability (What it is the likelihood of the Architecture of Instructional Process being used?) __
3. Value
   3.1 Work time benefits __
   3.2 Work quantity benefits __
   3.3 Work quality benefits __
   3.4 Cost benefits __
4. Do you expect the Architecture of Instructional Process Framework to have an impact (change the way of doing things) __

E. Please rate with 1-almost none; 2-some effects; 3-big effect; 4-transformational effect, the DMSS capabilities

1. Functionality (How useful it is?) __
2. Usability (What it is the likelihood of the DMSS being used?) __
3. Value
   3.1 Work time benefits __
   3.2 Work quantity benefits __
   3.3 Work quality benefits __
   3.4 Cost benefits __
4. Do you expect the DMSS to have an Impact (change the way of doing things) __

F. Please state what other existing systems (approaches, methods, tool) you know and rate the DMSS in relation with these on:

1. Similarity (1- not at all similar; 2- in part; 3- almost; 4- most similar)

………

……….

………

2. Interoperability (1- not at all; 2-in part; 3- almost; 4- fully interoperable)

………

………

………

3. Integration (1- not at all; 2- in part; 3- almost; 4-folly integrated)

………

………

………

G. Please comment on the impact that the DMSS can have (if any) on your domain of activity.

1. What (the system as a whole and/or components of the system)?

   ___

2. When (time wise; phase wise)?

   ___

3. How (what the impact will be)?

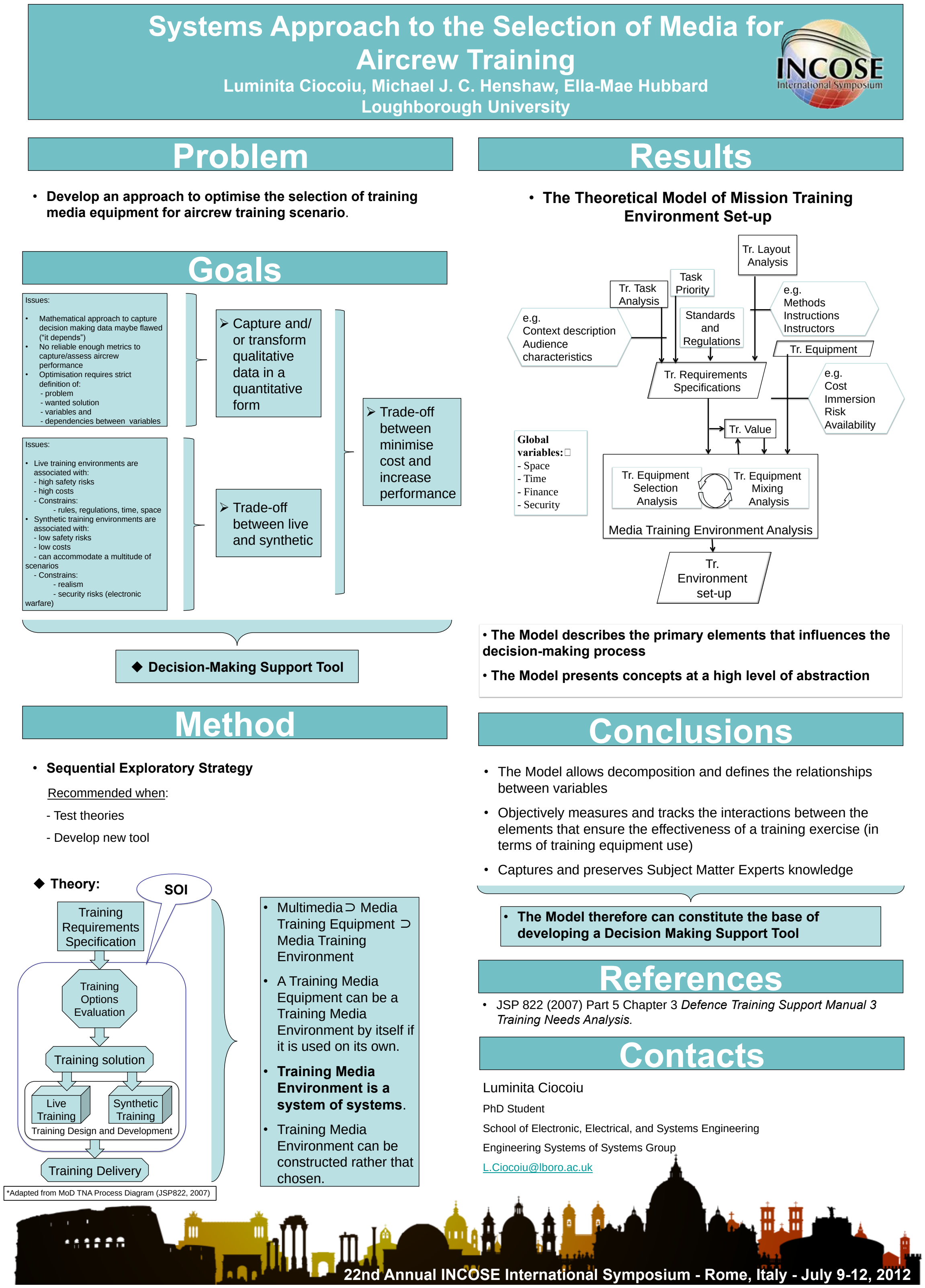
   ___

4. Please give details on what you think it needs to be done to achieve impact.

   ………….

Thank you!

Appendix 19: Ciocoiu, L., Henshaw, M. J & Hubbard, E. (2012). *Systems Approach to the Selection of Media for Aircrew Training*, 22nd Annual INCOSE International Symposium, Rome, Italy, 9-12 July.



Appendix 20: Ciocoiu, L., Henshaw, M. J. & Hubbard, E. (2012). *A systems-of-systems approach to the development of flexible, cost-effective training environments*, IEEE 7th International Conference on System of Systems Engineering, Genoa, Italy, 16-19 July

A systems-of-systems approach to the development of flexible, cost-effective training environments

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Abstract - *In today's aircrew training context, although there is an abundance of training systems that can enhance training and reduce costs, the challenge for the military training organizations to select the most cost-effective training systems to address their immediate and future needs is unresolved. The urgency of this dilemma is exacerbated by shrinking defense budgets. This paper shows how the systems engineering perspective can help the decision-making process for selecting the training media equipment to construct a cost-effective training media environment. A multidisciplinary approach and systems engineering techniques were used to develop a theoretical model of the Mission Training Environment arrangement . Implications of the approach, such as that the training environment can be viewed as a system of systems and that the choice is based on combination of equipment, will be discussed.*

Keywords: Training System, Training Environment, training media, LVC, decision-making, systems of systems.

1 Introduction

In the aircrew training domain, research has intensified in an effort to provide solutions that will ensure an increase in pilot performance (the new operational equipment and environment is more challenging) while there is also a reduction in costs (make the best of existing systems) without compromising safety (for aircrew and civilians).

Lower safety risks, reduced costs and increased operational readiness are benefits offered by the virtual environments. However, virtual environments come in many forms (from virtual simulation to live simulation) and, furthermore, the importance of training in a live environment cannot be underestimated. Therefore, an obvious direction in research is to explore the Mixed Media Training Environments benefits for aircrew training.

Such Mixed Media environments are rarely used (and even more rarely designed); they are constructed on an ad hoc basis as a bottom-up development for a specific exercise, at a specific location and then torn down when the exercise has finished [1]. This makes them difficult to research.

1.1 Cost and opportunity

Asymmetric warfare and shrinking budgets are demands that influence how the military prepares for its activities. Furthermore, these shape the defense industry in terms of development of products and services that aid the process of preparedness of the military, which has resulted in an abundance of "off the shelf" products ready to be used in training programs. Recent developments in the simulation domain have also resulted in high quality products that offer new possibilities to achieve cost-effective training [2], [3].

However, the lack of measurement techniques to assess the benefit of using particular systems in particular ways pose difficulties when it comes to deciding which is the optimum mix of products and services to be used to deliver a cost-effective training exercise.

1.2 Media and aircrew training

The matter of choosing the right mix of training media equipment to deliver cost-effective aircrew training is a question that, in one form or another, has been researched for some time within various domains and, despite the progress made, there are still some issues that need to be resolved [2].

Besides the lack of measurement techniques highlighted earlier, another issue is that although there is a common understanding of the meaning of Live, Virtual and Constructive (LVC) concepts, such that Live means real people operate real equipment; Virtual means real people operate simulating systems; and Constructive means simulated people are operating simulated systems [4], there is no commonly accepted classification and concomitant definitions of media encompassed within the training systems [2]. As a result, terms such as "blurred boundaries" and "blended technology" [1], [2] are more often used.

There is also the problem of capturing and integrating different types of data, such as qualitative data and tacit knowledge, into a rigorous, objective analysis that can aid the process of selecting the training media (equipment) to create an optimum training environment to deliver a cost-effective training exercise.

1.3 The question

With all this in mind, there is an unresolved question of how to create an optimum training media environment to deliver a cost-effective training exercise. This is the question to be answered within this research.

2 Approach

In trying to address as many issues as possible, in an integrative way for the benefit of the overall solution, a multidisciplinary approach was taken to define the problem space and to search for solutions. Therefore, various views from disciplines, such as, Human Factors, Operational Research and Systems Engineering have been taken into account.

2.1 Systems Engineering perspective

A Systems Engineering approach [5] is usually recommended when the problem has a high degree of complexity and there are systems integration challenges. The approach allows the engineer to deal with the complexity by decomposition of concepts and analysis of smaller problems, whilst maintaining focus on the potential interactions between such problems. Furthermore, it helps to define the environment and the boundaries of a problem [6].

The standards and guidelines for System Engineering are usually directed more towards development of new systems, rather that optimization of extant systems, although in practice they are applied to both new and extant systems. For development of extant systems, other approaches that are more specific to Operational Research domain are recommended.

Nevertheless, the inherent holistic thinking and multidisciplinary characteristics of the systems engineering approach makes it ideal to be followed in the present case, as it allows and encourages consideration and integration of multiple perspectives.

2.2 Operational Research

Finding the balance between LVC looks like a straightforward problem to be solved through application of an optimization technique, as such numerical techniques are often used to balance costs against effectiveness [7], [8]. But to be able to apply an optimization technique, certain steps have to be followed and certain criteria have to be satisfied, such as that the problem, the desired solution, the variables, and the dependencies between variables require strict definition [8].

The mathematical optimization models are designed to optimize a specific objective criterion which is subject to a set of constraints and the solution of the model is feasible only if satisfies all the constraints [7]. Therefore, the quality of the solution depends on the completeness of the model through which real-world parameters are reduced or lumped together into assumed real-world parameters. If the abstracted model is incomplete, the solution may not be optimal for the real world system and this raises concerns regarding the adequacy of the mathematical model. This may raise some conflict between the traditional parsimonious modeling approach of finding the simplest model which represents the situation and the SE approach, which focuses on a holistic and integrative view.

Researchers have drawn attention to the fact that human behaviour must also be taken into account when constructing these models to ensure that the solution is adequate and there is no possibility to even fail [8] and that means that human factors data need also to be incorporated and express in these models.

Furthermore, when the context of a system varies greatly, optimization can provide only a short-term advantage and may not be the best solution to make the system more efficient. Fisher [9] also points out that, although optimization is a good technique to increase the efficiency of traditional systems, optimization may undermine adaptability and can become inefficient as the circumstances on which the systems are operating are changing (e.g. increased variability of context = changing training requirements). Users may also be reluctant to repeat the optimization when circumstances change, leading them to rely on inaccurate information.

The application of optimization techniques to solve the problem of finding the balance between LVC for construction of the training media environment for a given training exercise should not be disregarded, but more work is required to fully accommodate all the necessary criteria within the optimization technique for it to be adequate.

2.3 Human Factors and Training Needs Analysis

The purpose of a training exercise, whether it takes place in a live, virtual or mixed media environment is to teach the trainee new knowledge and skills (or develop exiting knowledge or skills). The environment and the method chosen to train have not only to ensure the acquisition and development of skills and knowledge but also to ensure that these skills and knowledge are transferable to real, live situations.

Therefore, two additional variables must be taken into account to decide on the most appropriate arrangement for a training environment. These are degree of transferability of skill and knowledge learned in the training environment, and individual cognitive particularities of trainee.

Distinctions can be drawn between different types of training exercises based on learning stages. Meador [10] makes a distinction between acquisition and retention (or reacquisition), and Frank et. al [1] distinguish between Familiarization, Acquisition, Practice and Validation in their FAPV model. These distinctions have a significant impact on establishing the context of a training exercise and defining the training requirements.

Training requirements are usually derived from the analysis of training needs. Figure 1 shows the TNA (Training Needs Analysis) process. The diagram is an adaptation of the UK MoD TNA Process Diagram depicted in JSP822 report [11], [12].

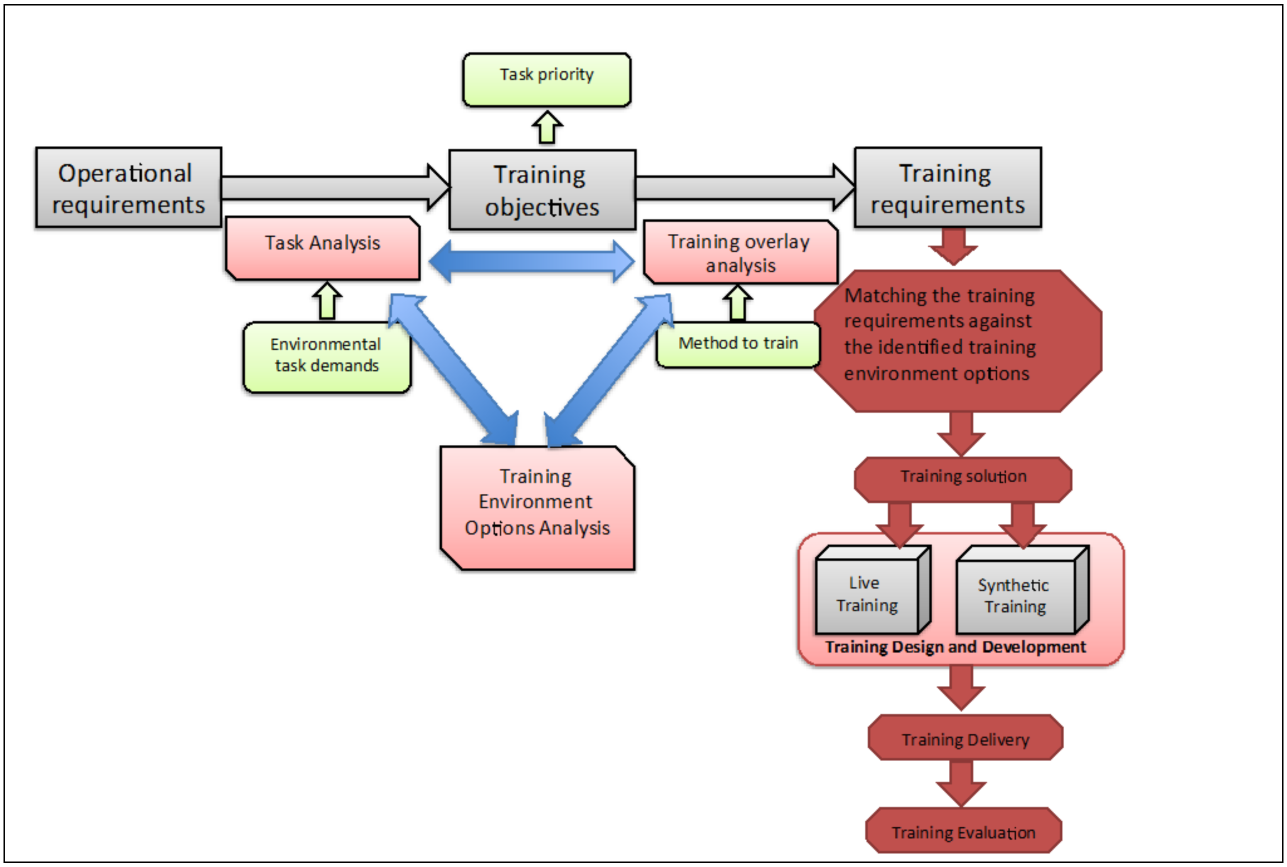

Figure 1. TNA Process Diagram

As can be observed from Figure 1, human factors particularities are captured at the training needs analysis stage that precedes the design and development phase of a training exercise. Furthermore, the training media environment system is decided based on the training requirements resulting from previous analyses.

However, this process is very restrictive. It is a major deficiency that such a process only allows the selection of one training environment system per exercise; it does not allow the possibility of choosing a combination of training systems to create a training environment. A combination may prove to be more cost-effective because it will maximize the usefulness of the available resources. Furthermore, the process of Figure 1 does not take into consideration factors such as schedule, maintenance, cost and other variables that impact the cost-effectiveness of a given training environment.

3 Method

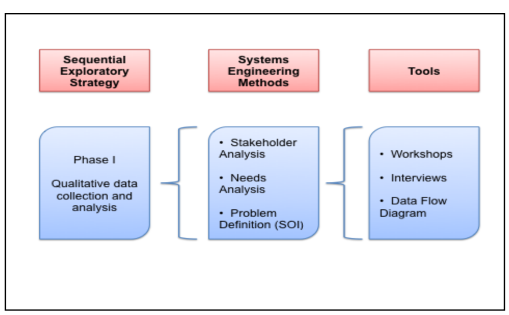

Figure 2. Applied methodology, methods and tools

Because of the high importance of defining and representing the problem through as accurate a model as possible, and because of the issues with this, such as the need to integrate quantitative and qualitative information into the model, a *mixed methods methodology (sequential exploratory strategy)* [13] was used in parallel with *systems engineering methods* to develop a Theoretical Model of Media Environment arrangement for the Mission Training Scenario. The methodology, and the process of methods and tools that was followed are presented in Figure 2.

4 Results

A Theoretical Model of Training Environment arrangement that is presented in Figure 3, has been developed based on the analysis of the information captured from Subject Matter Experts (SME's). The theoretical model is represented by a data flow diagram.

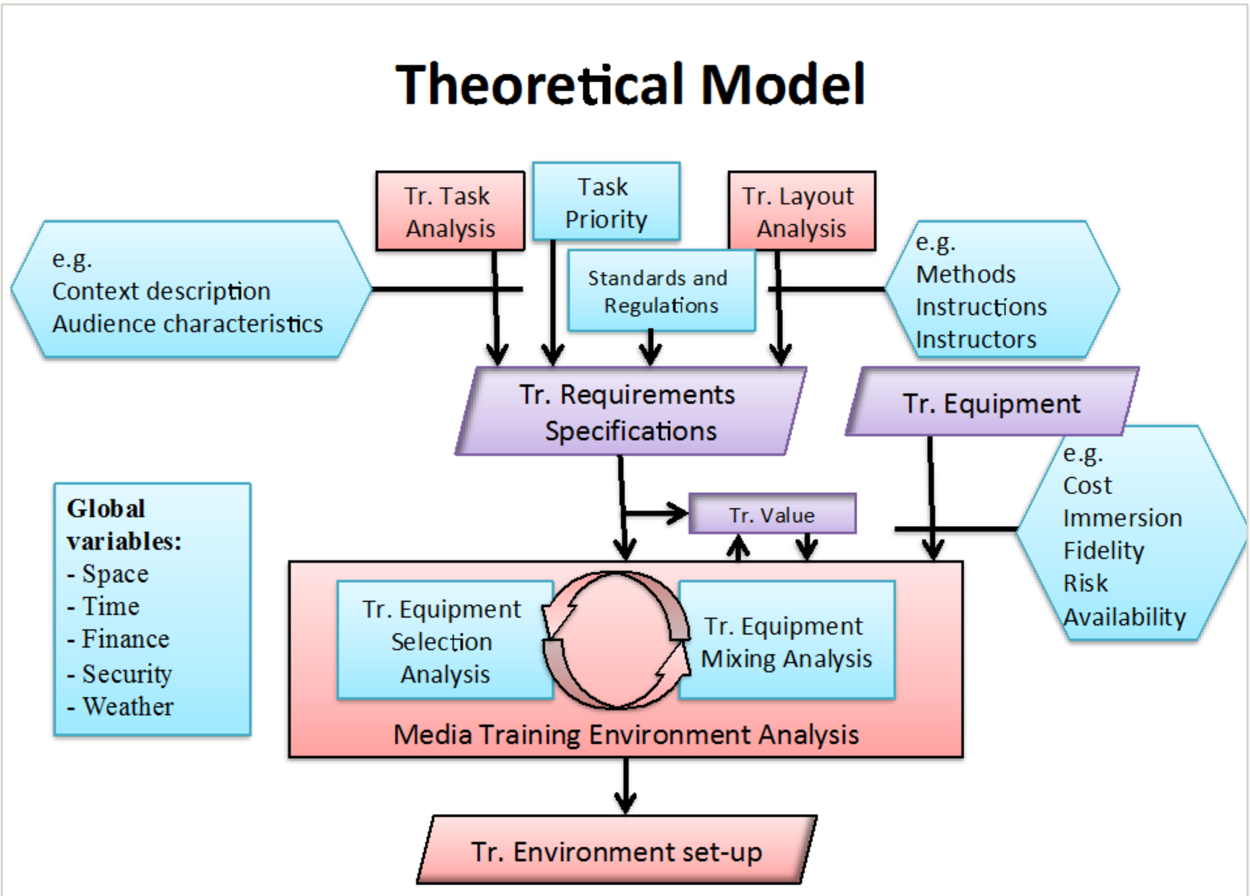

Figure 3. Theoretical Model of Training Environment arrangement

The model presents the System of Interest (SoI), which is the “Training Media Environment Analysis”, and the Wider System of Interest (WSoI), which is represented by the factors that influence the behaviour of the SoI.

The model shows the input data necessary for the system, the needed transformation functions and the required output. Furthermore, some specific and global variables upon which the decision making of selection relies are highlighted.

5 Discussions

The idea put forward by the model is that, if the properties exhibited by the relationship between training equipment and LVC technology, Media, Training Equipment and Training Environment are investigated, the following may be concluded:

Media ⊃ Training Equipment

And,

Training Equipment = Training Environment

And as,

Training Equipment = Training System

Then,

Training Environment = Training System

However, this relationship is true only in the case when (after the decision that was made on the selection of the training equipment) the result is to use only one training equipment to deliver the training exercise (for example, a ground base simulator).

If the decision is to use more than one training equipment to deliver a training exercise, then the following can be concluded:

Media ⊃ Training Equipment ⊃ Training Environment

Then if,

Training Equipment = Training System

Training Environment = Training System

Means that,

Training Environment Sub-system = Training Equipment Systems

Furthermore, if we look at the developments made in the synthetic training domain it can be observed that there is an abundance of off the shelf products that are cheaper than bespoke ones and highly efficient in delivering cost-effective training. But these training systems have not necessarily been designed to be used alongside other training systems.

Because of this interoperability particularity, we propose that the Training Media Environment should be considered to be a Training System of Systems rather than a Training System. Therefore, it can be considered that the setting up of a training media environment is not only a matter of identifying and selecting a cost-effective training system but rather a matter of constructing and managing a System of Systems Training Environment that comprises a mix of LVC technologies.

Furthermore, as the emergent behavior of a system depends on the interactive behavior of its components, the decision of selecting the components of a system is, or should be, directly influenced by the effect resulting from the combination of different components. This means that, the decision making process of selection of the training media equipment to construct a training media environment should be tightly coupled with the training systems mixing analysis.

The developed Theoretical Model of Training Environment Set-up that is proposed in this paper is the first step in a research project the aim of which is to develop a tool to help decision makers in selecting the most appropriate blend of training media to construct a cost-effective training environment for aircrew training. By bringing together, data resulted from training needs analyses and training equipment analyses, coupled with the overall context variables, a more comprehensive tool to aid the decision making process can be built.

This theoretical framework will help the development of a tool that will integrate quantitative as well as qualitative data in its analyses. This will also be beneficial in capturing tacit knowledge that is usually lost when the experts that are making the decisions retire. Furthermore, this model will contribute towards making cost-effective decisions, because it promotes the idea of making the most out of the available resources.

6 Limitations

Although, the proposed theoretical model has been validated at the conceptual level, with the help of military aviation domain SME's, the verification process has not been carried out at this stage. The scope of model applicability is limited to the particular training application associated with mission training scenarios. Although, it is possible that it could be extended to other training applications and domains, there has been no attempt, so far, to validate it more widely.

Further development of the theoretical model may yield additional main variables that have not so far been captured; this will be tested during the next development phase.

7 Conclusions

In answering the question of how to create an optimum training media environment to deliver a cost effective exercise, this research proposes a novel, multidisciplinary approach to be taken forward.

The theoretical model that was developed at this stage represents a first step into integrating multiple types of data into an analysis that will help decision makers, in their process of building an optimum media training environment, to deliver a cost-effective training. The model comprises variables linked with human characteristics as well as with equipment characteristics. Furthermore, it incorporates some global variables that have usually been missed so far. The scope of the model is to address the more complex training needs of the future, and takes a wider perspective of the solution; hence may also generate more cost-effective solutions of greater flexibility.

Furthermore, significantly and explicitly the model includes consideration of human issues and because of this characteristic it could be applied to complex civilian roles as well (e.g. emergency response).

The approach that is put forward in this paper has its limitations, however, it offers an alternative, integrative way to explore the phenomenon of constructing Mixed Media Environments for the benefit of the next generation of aircrew training.

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