UNIVERSITY OF KWAZULU-NATAL

BRIDGING THE TRAINING NEEDS OF CYBERSECURITY PROFESSIONALS IN MAURITIUS THROUGH THE USE OF SMART LEARNING ENVIRONMENTS

By

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To my daughter Aaradhya,

who everyday kept asking me why I go to sleep so late at night...

ABSTRACT

Teaching and Learning confined to within the four walls of a classroom or even online Learning through Massive Online Courses (MOOCs) and other Learning Content Management Systems (LCMS) are no longer seen as the optimal approach for competency and skills development, especially for working professionals. Each of these busy learners have their own training needs and prior knowledge. Adopting the *one-size-fits-all* teaching approach is definitely not effective, motivating and encouraging. This is why this research presents the use of SMART Learning Environment that makes use of *Intelligent Techniques* to personalise the learning materials for each learner. It has been observed that on one hand the country is not able to provide the required number of IT professionals with the desired skills and on the other hand, the number of unemployed graduates in areas other than IT is increasing. This mismatch in skills is becoming a pressing issue and is having a direct impact on the ICT Sector, which is one of the pillars of the Mauritian Economy.

An in-depth Literature Review was carried out to understand the training needs of these Cybersecurity professionals and also to understand the different *Intelligent Techniques* that can be used to provide personalisation of learning materials. Data was collected during three phases, namely an Expert Reference Group Discussion, a pre-test questionnaire and a survey questionnaire. The Expert Reference Group Discussion was carried out to further shed light on the research question set and to further understand the training needs and expectations of Cybersecurity professionals in Mauritius. A SMART Learning Environment making use of Artificial Neural Networks and Backpropagation Algorithm to personalise learning materials was eventually designed and implemented. Design Science Research Methodology (DSRM), Activity Theory, Bloom's Taxonomy and the Technology Acceptance Model were used in this study. Due to the inherent limitations of the models mentioned, the researcher also proposed and evaluated an emergent conceptual model, called the SMART Learning model. The major findings of this research show that personalisation of learning materials through the use of a SMART Learning Environment can be used to effectively address the training needs of Cybersecurity professionals in Mauritius.

Keywords: SMART Learning Environment, Cybersecurity, Design Science Research Methodology (DSRM), Activity Theory, Bloom's Taxonomy, Technology Acceptance Model, Artificial Neural Networks (ANN), Backpropagation (BP) Algorithm.

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LIST OF ABBREVIATIONS

API	Application Programming Interface
BOI	Board of Investment
BPO	Business Process Outsourcing
CEH	Certified Ethical Hacker
CIB	Central Informatics Bureau
CISA	Certified Information Security Auditor
CISM	Certified Information Security Manager
CISSP	Certified Information Systems Security Professional
CPD	Continuous Professional Development
EDB	Economic Development Board
GTES	Graduate Training for Employment Scheme
HEI	Higher Education Institution
HR	Human Resources
HRDC	Human Resource Development Council
ICT	Information and Communications Technology
IDI	ICT Development Index
ISO	International Organization for Standardization
ITU	International Telecommunication Union
KPO	Knowledge Process Outsourcing
MCTI	Ministry of Technology, Communication and Innovation
MOOC	Massive Open Online Courses
NCB	National Computer Board
OTAM	Outsourcing and Telecommunications Association of Mauritius
SEM	Structural Equation Modeling
SLE	SMART Learning Environment
SIL	State Informatics Limited
TEL	Technology Enhanced Learning

"Everybody is a genius. But if you judge a fish by its ability to climb a tree, it will live its whole life believing it is stupid."- Albert Einstein.

CHAPTER ONE: INTRODUCTION

"The formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill. To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science." - Albert Einstein

1.1 Introduction

Some of the earliest written records show that formal education began sometime between 3000 and 500 B.C.E. Societies have always seen education as a means for growth and development. Indeed the development of society has been triggered by new challenges and opportunities and humankind has always been prompt to react to these challenges resulting in its overall progress. Society progressed through some well-defined stages of development, including nomadic hunting, agrarian society, industrial society and information society. All along, the role of education has been instrumental for the development of society. Looking across the horizon, it can be seen that progressively, our society is moving towards another stage of development which will be known as society 5.0, where data collected will be processed into a new form of intelligence through Artificial Intelligence and other mega trends in technology. One of the issues lies in whether our current form of education will still be robust enough to provide the necessary societal capacity to organise resources to meet the new challenges and opportunity that lie ahead. It is beyond doubt that teacher-centered learning has significantly transformed our society and has had its load of contribution. Our present digital era is radically transforming the educational landscape and education for the future would perhaps requires a new paradigm shift. Criticism against teacher-centred learning include the fact that this form of teaching provides little interaction in most cases and gives little opportunities for the learner to reach higher levels of the cognitive process since the latter is most of the time passive recipients of knowledge. Teachers and Learners can tap into the full benefits of ICT to make the learning experience more enriching and fruitful. One of the possibilities lies in a shift from teacher-centered learning to student-centered learning in the form of AAAL; Anytime, Anywhere, Anybody Learning. Learners have to be trained for a world that is rapidly changing and what is being taught today might be obsolete tomorrow. In fact, learners need to be taught how to learn.

1.2 Overview of the Republic of Mauritius and ICT Sector

The Republic of Mauritius is a small Island in the Indian Ocean, situated around 2,000 Km off the East of the African Continent and has a total population of around 1.3 million inhabitants (Economic Development Board Mauritius, 2019). The ICT sector has been able to position itself as one of the major pillars of the Mauritian Economy. A number of ICT companies engage in BPO activities and software development. As per ITU's ICT Development Index 2017, Mauritius ranks itself 72nd in the world and 1st in Africa with an ICT Development Index (IDI) of 5.88 (ITU, 2017). The ICT/BPO sector presents tremendous opportunities for Mauritius in its endeavour to become a high-income economy. The Economic Vision 2030 of the Government of Mauritius aims at transforming the ICT industry into a key sector by fostering innovation & creativity and developing a sustainable & high value added-economy that will provide more accessible and higher-value opportunities for Mauritian citizens (Economic Development Board, 2018).

The Information and Communication Technology/Business Process Outsourcing (ICT/BPO) sector remains a buoyant and growing one for economic growth and employment in Mauritius. Given the dynamic and fast-paced nature of the sector, the skills of the workforce also need to concurrently keep up with the pace. Human talent with the right skill sets will continue to be the key, among other factors, for the building of a vibrant and diversified ICT/BPO sector in Mauritius (HRDC, 2017). The Human Resource Development Council (HRDC) of Mauritius has been vested with the responsibility to look after and promote the development of the labour force in Mauritius in line with the requirements of a fast growing economy (HRDC, 2017). The ICT/BPO industry has maintained its strength towards high-end activities. Total employment in the ICT-BPO industry has crossed the 20,000 threshold and stood at 23,000 in 2016 as shown in the figure below

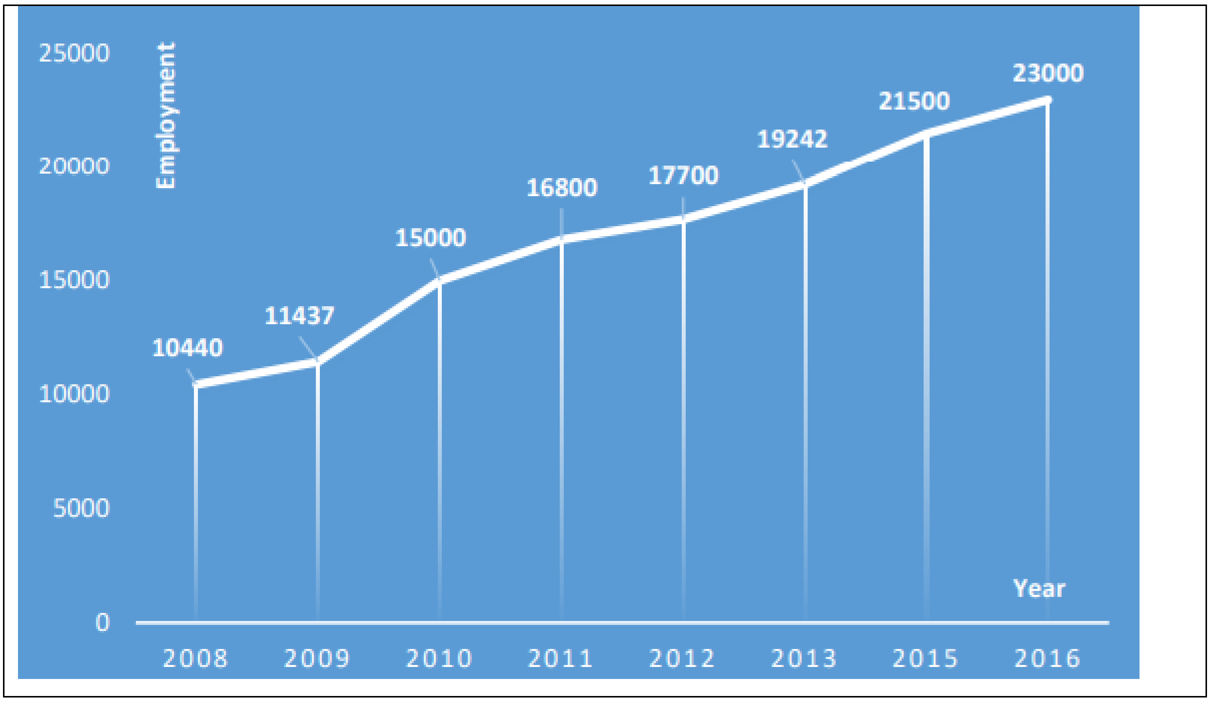


Figure 1. 1: Employment in the ICT Sector of Mauritius (2008-2016)

(Source: Adapted from Industry Review 2016 ICT/BPO, BOI 2016)

The breakdown of employment per sub-sector is shown below

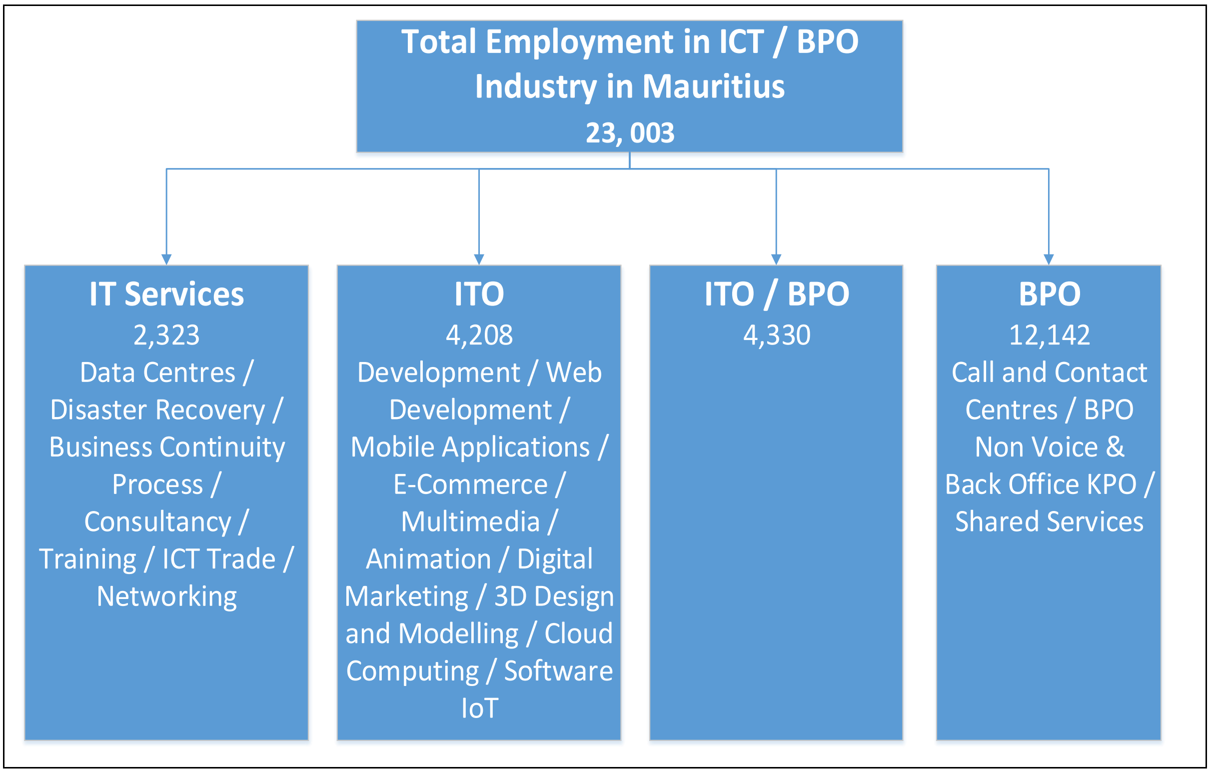


Figure 1. 2: Breakdown of Employment in the ICT Sector of Mauritius per sub-sector

(Source: Adapted from Industry Review 2016 ICT/BPO, BOI 2016)

Mauritius has to remain competitive in the IT industry by ensuring that the ICT labour force is kept up-to-date with the latest technologies. Employer demand for a skilled workforce in the ICT Sector will continue in the global competitive marketplace and it is important that education and training supply produces people in the right number with relevant skills and qualifications to meet this demand (HRDC, 2017). The latest figures available still position the ICT-BPO sector as one of the pillars of the Mauritian economy and with some 850 ICT-BPO based enterprises, the ICT-BPO sector of Mauritius is seen as one of the richest and most vibrant technology ecosystems in Africa (Economic Development Board Mauritius, 2019).

1.3 Statement of the problem

The current problem with the ICT/BPO sector of Mauritius is the lack of trained professionals with the proper skills to respond to the needs of this bustling sector. This has often been described as 'Skills Mismatch' and is very detrimental for the ICT sector whereby a number of businesses prefer to move their businesses to other locations where the people are skilled and properly trained. This has been described in a report carried out by the Human Resource Development Council (HRDC) of Mauritius where it is mentioned that "skills mismatches in the ICT labour pool are a particular concern given the importance of this sector in the Government's growth strategy" and further elaborates by mentioning that "…the persistent and growing mismatch between workers' skills and market needs that plagues the economy generally is also apparent for the ICT labour pool" (HRDC, 2017). The HRDC has also carried out a survey where it was found that the enterprises operating in the ICT sector are not satisfied with the level of preparedness of the potential recruits, whether 'freshers' or those having work experience. Even the World Bank Group has recognized this mismatch by stating that "employer surveys suggest that the ICT sector is facing a labour shortage that is expected to continue or worsen over the next five years, and for which the key factors are a lack of sufficient work experience and low qualifications in both technical and soft skills" (HRDC, 2017).

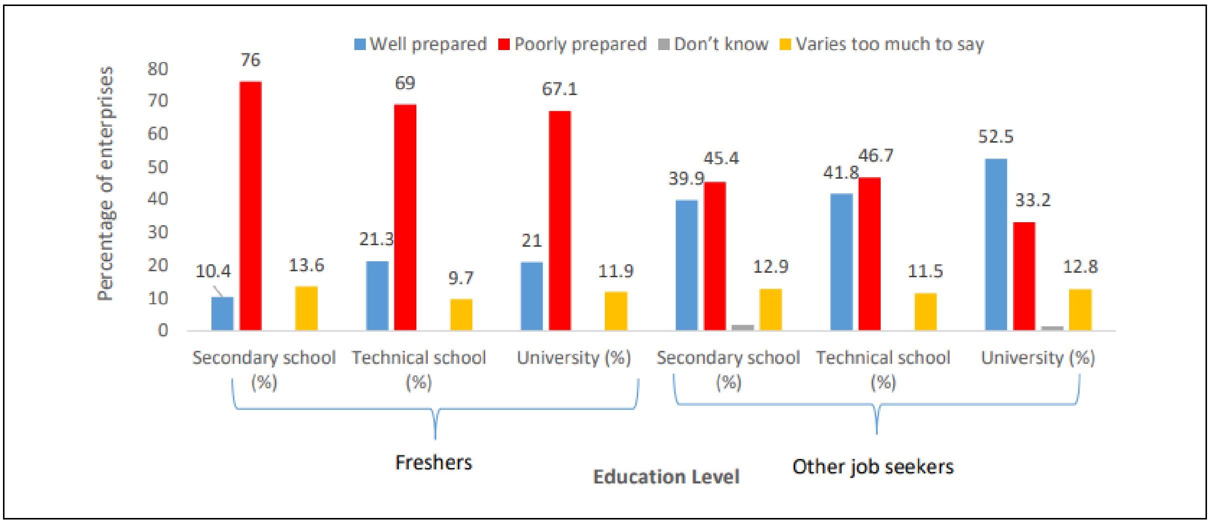


Figure 1. 3: Perception of employers w.r.t preparedness of last 2 years recruits

(Source: HRDC – skills study report for the ICT Sector, 2017)

The Ministry of Technology, Communication and Innovation (MTCI) of Mauritius has reaffirmed the above and is even considering this as a major problem by stating that "like many countries, Mauritius is suffering from a workforce mismatch phenomenon in ICT where the requirements of the industry concerning labour are not being met. At the Ministry, this is a priority and we are actively working on solutions to this major problem," and further argues that "the Mauritian Government is fully conscious that the lack of ICT Professionals in the job market is a serious impediment to the development and expansion of the ICT/BPO sector." (MCTI, 2018)

Furthermore, it can be observed that the number of unemployed graduates from other sectors of the economy is increasing and these are encouraged to do a conversion course in IT, where there is a great demand. The Government of Mauritius is giving its full support to address this issue and has announced in its budget speech 2015/2016 that these unemployed graduates would be given necessary facilities to follow a conversion course, namely through the GTES programme. The latter argues that "there are presently some 3000 *unemployed graduates*, whose training does not match market requirements'. These unemployed graduates are mostly from the field of Agriculture and Human Sciences. To improve their chances of getting a job, the University of Mauritius and other qualified institutions will develop tailor-made crash courses in fields with high job prospects, namely in the field of ICT/BPO," (GTES, 2016).

Continuous learning and constant up skilling of the ICT labour force is a must for this crucial sector of the Mauritian economy. Face-to-face learning, e-learning, and other traditional methods are necessary, but do not appear to be sufficient to address the skills gap in the case where training needs and learning styles of everyone is different. A **'one-size-fits-all approach'** is not beneficial and does not encourage learning effectiveness and efficiency as well. Some learners might be learning concepts that are too easy for them whereas others might be learning concepts that are far too complex for them to start. Some recruits in this sector already have some experience and require some minor up skilling whereas some recruits are completely new in this field, doing a conversion programme and would require a complete coverage of the concepts, starting from the very basics. This leads to a situation where the learner ends up being frustrated and does not eventually meet the learning objectives or pathways initially set. This situation is depicted in the figure below, where it should be understood that every learner has their own specificities and abilities.

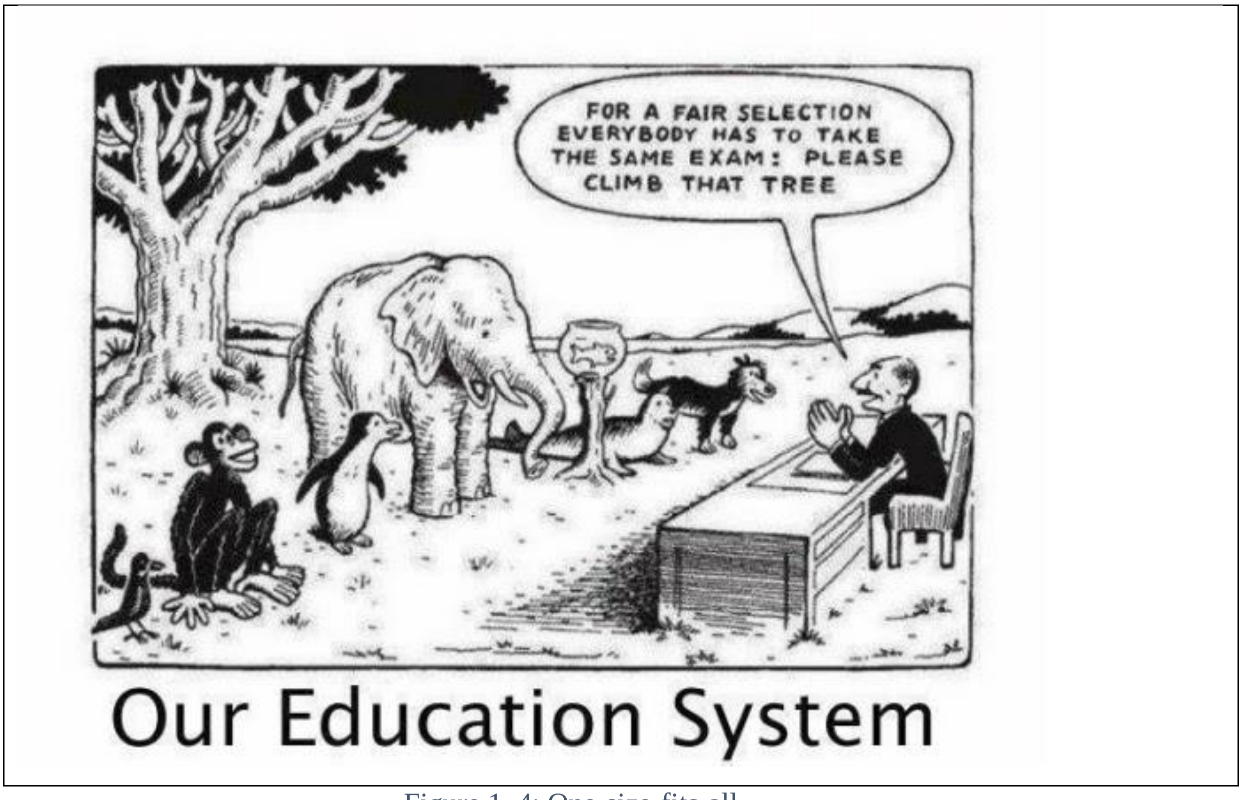


Figure 1. 4: One-size-fits-all

(Source: Champion News.net, 2013)

This phenomenon is even more clearly visible with the concept of Massive Open Online Courses (MOOCs) e.g. Coursera or edX where the dropout rate is high and very often the learners are 'disconnected'. Top Universities in the world such as Harvard and MIT joined the MOOC bandwagon to propagate knowledge. Despite the millions of subscription for the Harvard MOOC, only 10% of students were completing the courses. Feedback from students show that the content of the courses did not suit their current knowledge level and that the way the course content was presented decelerated their learning rate. Onah et al (2014) argues that although thousands of participants enrol on MOOC courses, the completion rate of most of these courses is below 13%. Hence the concept of "one size fits all" was questioned by researchers who brought forward the concept of learning styles and prior knowledge relationship to learning process.

1.4 Purpose of Research

The focus area of this research is to design, develop and evaluate a framework for a SMART Learning Environment that will be beneficial for the continuous learning of Cybersecurity professionals in the ICT Industry of Mauritius. Cybersecurity is a highly dynamic field and the motivation for choosing Cybersecurity as the area to be considered in this research is depicted in Sections 1.8.1 and 2.13 of this thesis. The proposed SMART Learning Environment will provide personalized and adaptive learning materials for the learner/trainee, bearing in mind that all learners/trainees are different and evolve in different context. Personalisation and adaptivity of the SMART Learning Environment is achieved by using 'Intelligent Techniques'.

The importance of this research lies in the fact that with the traditional web-based learning for continuous improvement of these ICT Professionals, very often there is a lack of commitment/involvement of the learners. Personalisation of learning materials can be seen as a viable alternative instead of providing the same learning materials for everyone.

Specifically and in more detail, this research sets out to:

- Conduct an investigation on the current status of Cybersecurity education in Mauritius and collect information about the means and ways used for training.

- Assess the importance of having SMART Learning Environments making use of personalisation and adaptation in today's learning process.
- Design and develop a SMART Learning Environment to provide personalisation of learning materials based on the differences of the learners / trainees.
- Evaluate the effectiveness of the proposed SMART Learning Environment as compared to traditional means of training.

1.5 Research Questions and Objectives

The main research question for this study is:

"How can the training needs of Cybersecurity Professionals in Mauritius be addressed through the use of a SMART Learning Environment providing personalisation of learning content?"

The associated objective of this research is to design and develop a SMART Learning Environment that allows the personalisation of learning materials for learners / trainees. The research objectives (ROs) of the study can be listed as follows:

Table 1. 1: Research Objectives

Research Objective	**Description**	**Answered Through / Source of Information**
(RO1)	Explore the training needs of Cybersecurity professionals in the ICT Sector of Mauritius	Online Desktop Research, Government Published Data and Expert Reference Group Discussion.
(RO2)	Explore the effectiveness of the current learning methodologies in bridging the training needs of ICT Professionals in Mauritius	Online Desktop Research, Government Published Data, Expert Reference Group Discussion and Survey Questionnaires.

(RO3)	Analyse how SMART Learning Environments providing personalisation of Learning Contents operate.	Online Desktop Research - Conference and Journal Papers
(RO4)	Analyse the different Intelligent Techniques available for implementing SMART Learning Environments	Online Desktop Research - Conference and Journal Papers
(RO5)	Design, Develop and Evaluate a SMART Learning Environment	Design Science Research Methodology
(R06)	Assess the effectiveness of the SMART Learning Environment in providing Continuous Learning for Cybersecurity professionals in the ICT Sector of Mauritius as compared to traditional Technology Enhanced Learning	Survey Questionnaires

To achieve the above objectives the following Research Sub-Questions (RSQs) needs to be answered in this study:

Table 1. 2: Research Sub-questions

RSQ1	What are the training needs of Cybersecurity professionals in Mauritius?
RSQ2	What is the effectiveness of the current learning process in addressing the requirements of Cybersecurity professionals in Mauritius?
RSQ3	What are the most effective intelligent techniques available and how can these be leveraged to develop a SMART Learning Environment?

1.6 Significance and benefits of the Study

This section highlights the potential contribution associated with this study and outlines the potential beneficiaries as well.

1.6.1 Potential Contribution

The major outcome of this research is the design and development of a framework / artefact using Design Science Research Methodology that will help to investigate how SMART Learning Environments providing personalised learning materials can be used to provide continuous learning, up-skilling and re-skilling of professionals in the ICT sector of Mauritius.

Further contributions of this study include:

- Adding to the body of knowledge of Technology Enhanced Learning by highlighting the current trends and establishing the future directions, namely in the form of SMART Learning
- Deepening the understanding of frameworks for SMART Learning Environments
- Identify the training needs of the professionals of the ICT Industry of Mauritius.
- Provide a more efficient way of up-skilling and re-skilling of professionals in the ICT sector of Mauritius

1.6.2 Beneficiaries of this research

The findings of this research will be beneficial to

- Researchers in the field of ICT in Education and Technology Enhanced Learning
- Professionals in the ICT Sector of Mauritius
- Training Managers for the ICT Sector in Mauritius
- The learning community as a whole since the SMART Learning Environment developed, with some localisation/modification, can be used for any learning process, whether it is for the Industry or Academia.
- The Government of the Republic of Mauritius in its attempt to provide qualified and trained professionals to respond to the ICT needs of the country.

1.7 Scope of the research

1.7.1 Context and Domain of the research

- This research concentrates on developing and evaluating a SMART Learning Environment using personalisation of contents in the domain of the ICT Sector of Mauritius.

- Existing data and literature from the experience of participants, thus setting the context and creating a general frame of reference.

- Participants are professionals in the ICT Sector of Mauritius who are also continuous learners as per the requirements of this highly dynamic sector.

1.7.2 Delimiters and Limitations

- This research is targeted at ICT professionals in Mauritius but participants may also include international IT professionals who are working in companies in Mauritius. Indeed with ICT and BPO, there are a number of IT professionals from overseas but who are working in Mauritius.

1.8 Career Paths in the ICT Sector in Mauritius

The ICT/BPO Sector is a highly dynamic sector locally and abroad, aiming at creating jobs of the future. In the local context, the latest report of the Board of Investment (BOI) in 2016 claims that there 750 ICT-BPO companies in Mauritius employing around 23,000 persons and these figures are continuing to grow. Out of these 750 ICT-BPO Companies, 80% are small firms.

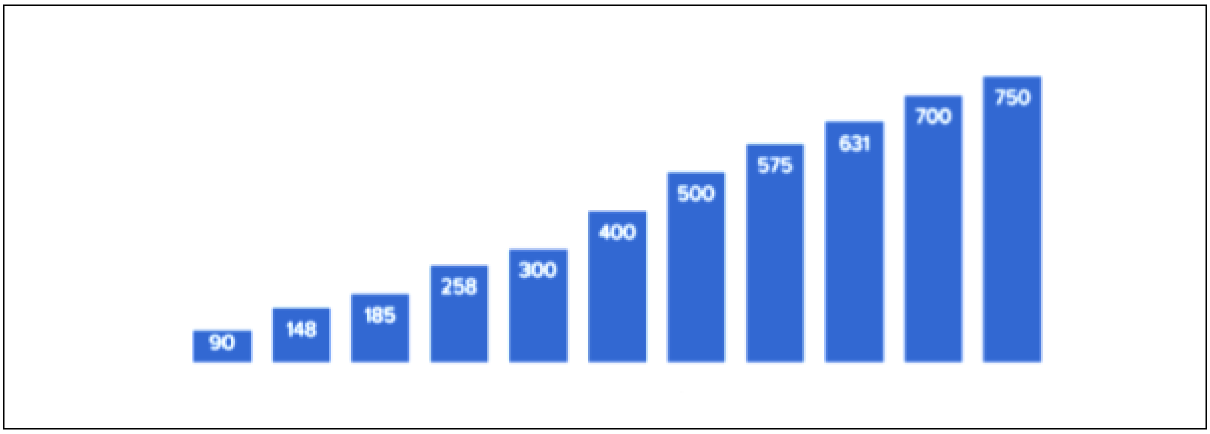


Figure 1. 5: Evolution of the number of ICT-BPO companies in Mauritius, 2006-2016

(Source: BOI, 2016)

The BPO segment remains the main generator for jobs with 53% of total employment in the segment of Call & Contact Centres, BPO Non Voice & Back office Knowledge Process Outsourcing (KPO), Shared Services (HRDC, 2017). To be able to fully understand the job title / specifications of ICT professionals in Mauritius, information was collected and synthetized from the major players / organisations in this sector. These include:

- Ministry of Technology, Communication and Innovation (MTCI)
- Outsourcing and Telecommunications Association of Mauritius (OTAM)
- National Computer Board (NCB)
- State Informatics Limited (SIL)
- Human Resource Development Council (HRDC)
- Board of Investment (BOI)

The different areas providing career paths in the ICT Sector of Mauritius (HRDC, 2017) are listed below:

- Cybersecurity
- Networking
- Software Development and Web
- Infrastructure and Systems
- Systems Design
- Service Management
- Software Testing
- Call Centre
- Business Process Outsourcing (BPO)

1.8.1 Career Paths in the area of Cybersecurity in Mauritius

With the world becoming more and more connected and with technology evolving at such a pace, the area of Cybersecurity currently faces many challenges and is highly dynamic one. Very often, the skills of hackers and other cyber criminals can outpace that of the professionals in the organisation. Hence the need for constant up-skilling of these professionals. The Government of Mauritius has identified Cybersecurity as one of the areas where professionals would be in high demand in the years to come (HRDC2017). For the purpose of this research, only one area, namely that of Cybersecurity has been considered. Information about this area was collected, compiled, summarised and then analysed. A complete description of the different job titles, responsibilities, qualifications and required competencies for a CyberSecurity Professional in Mauritius is presented in Annexure A. This shows that the main job profiles of Cybersecurity professionals in Mauritius include that of Information Security Officer, Information Security Analyst, Information Security Consultant and Chief Information Security Officer.

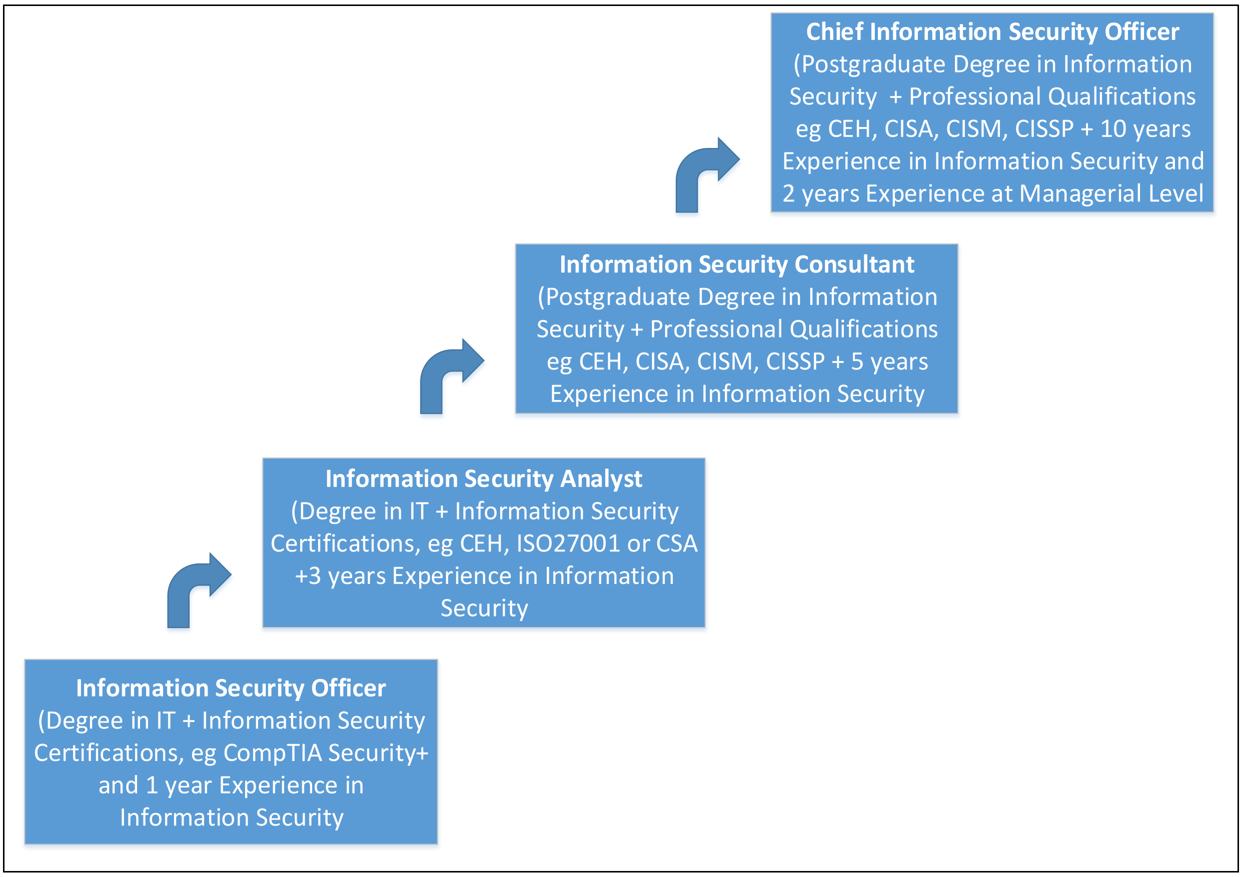


Figure 1. 6: Career Path in the field of Cybersecurity in Mauritius

(Source: Researcher's own construction)

Additional information about the area of Cybersecurity is given in section 2.14 of the thesis. The same process adopted may then be applied to the other areas of the ICT sector in Mauritius as identified in section 1.8.

1.9 Research Blue Print

Figure 1.7 illustrates the process model for the research study. It has been elaborated as a series of 14 stages. Stage 1 consists in formulating the research aims and objectives. Stage 2 involves elaborating the research questions. A thorough Literature Review is then considered in Stage 3. After initial information has been collected from stages 1-3, stage 4 implies the formulation of an initial conceptual model. This model is then validated and critically analysed through an Expert Reference Group Discussion in Stage 5. Through the Expert Reference Group Discussion, qualitative data is generated. Stage 6 involves data collection and analysis of this qualitative data. Stage 7 involves the formulation of a refined version of the proposed conceptual model and is thereafter referred to as the 'Finalised Conceptual Model'. Using Design Science Research Methodology (DSRM), the design and development of the SMART Learning Environment is described in stage 8. Stage 9 involves the selection of a pre-test sample of 20 Cybersecurity professionals operating at various levels for an initial feedback as required by the Design Science Research Methodology. Through the use of a Pre-test Questionnaire, qualitative data is collected from the pre-test sample of 20 Cybersecurity professionals. Stage 11 involves the iterative refinement of the SMART Learning Environment using feedback collected from the pre-test sample until consensus has been reached. Stage 12 depicts the testing of the SMART Learning Environment using a sample of Cybersecurity professionals identified. During this stage both qualitative and quantitative data is collected. Stage 13 involves assessing the effectiveness of the proposed SMART Learning Environment in bridging the training needs of Cybersecurity Professionals in Mauritius. Stage 14 presents the findings of this research to the different stakeholders. The whole process and the different stages outlined for this research is presented in Figure 1.7.

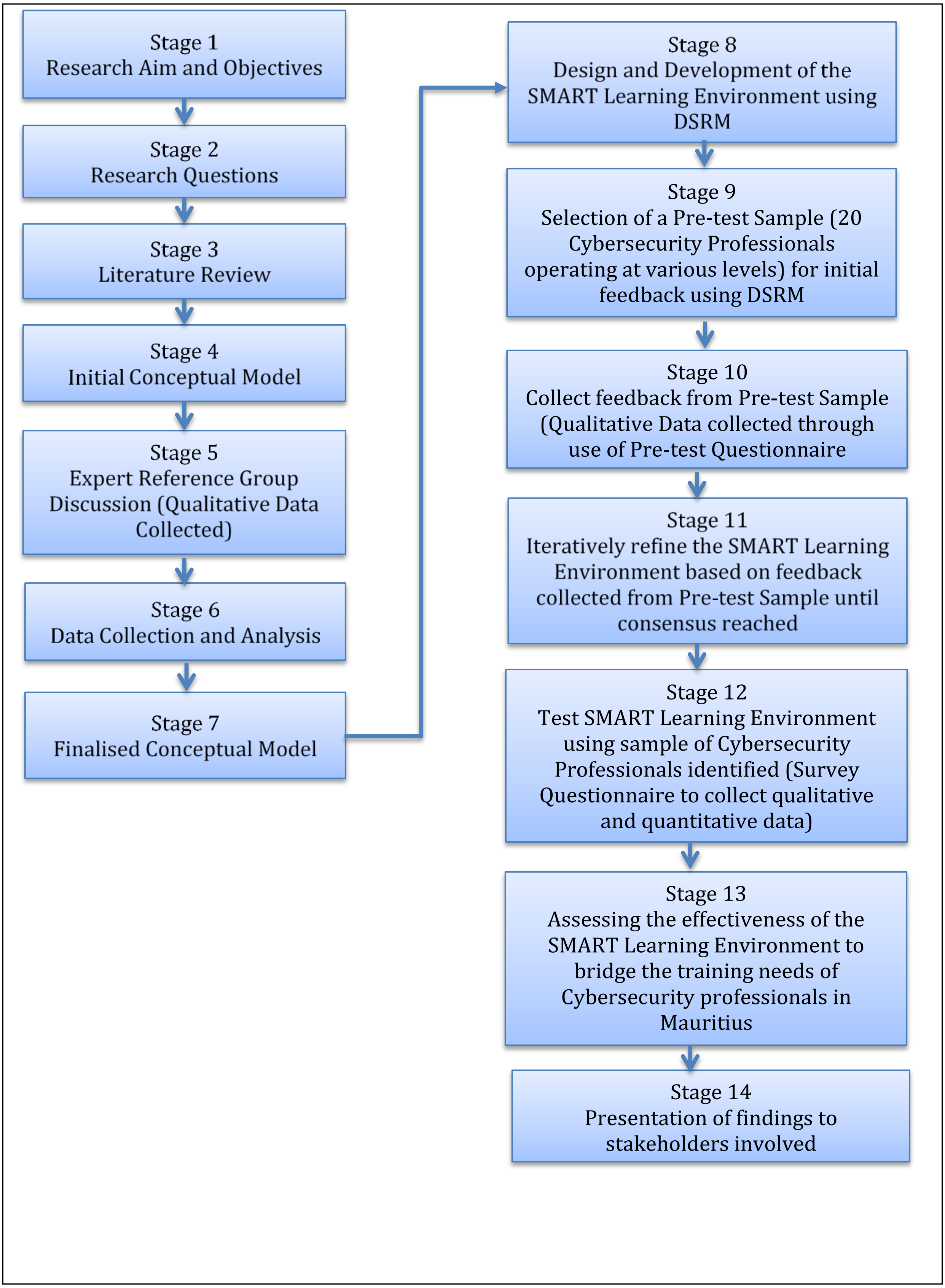


Figure 1. 7: Research Blueprint

(Source: Researcher's own construction)

1.10 Data Quality Assurance

One of integral components of Data Quality Assurance involves quality control of data gathered. It is essential that appropriate procedures and mechanisms are set in place before data gathering takes place. This can come at various stages throughout the research, namely data collection, data entry and data checking. For the purpose of this research, data will be collected primarily through the use of carefully planned Expert Reference Group Discussions and Questionnaires. Data entered in the SMART Learning Environment will then be validated through the use of validation rules, input masks and data checks will be performed to ensure the accuracy and completeness of the data.

1.11 Ethical Considerations

Ethical considerations in research is critical. One of the measures that would be adopted in this research is the informed-consent rule. Since this research targets at collecting data from an 'Expert Reference Group' and a sample of Cybersecurity professionals from the IT Sector in Mauritius, the consent process will ensure that these professionals are fully aware of the risks and benefits and will participate in this study in a voluntary way. Another criteria that will be ensured is the confidentiality and privacy of the respondents of this research. Responses from participants will be kept anonymous and identifying information will be removed.

1.12 Structure of Thesis

This research is presented in six chapters, which will be arranged in the following order:

CHAPTER ONE (Introduction): A thorough statement and analysis of the problem which helps to provide a general background and orientation to the study. The rationale for the study, research problem statement, objective of this study, key research sub-questions, significance of study as well as the scope and limitations of the study will be presented in Chapter 1.

CHAPTER TWO (Literature Review): Chapter 2 consists of the literature review as addressed by the main objective and the key research sub-questions. The chapter will review research studies from literature that are associated with Technology Enhanced Learning and SMART Learning Environments and helps in providing a number of alternatives to address the problem identified.

CHAPTER THREE (Theoretical Framework, Conceptual Model and Research Design): This chapter discusses the theoretical model namely, Design Science Research Methodology (DSRM) that was chosen to drive this research study. It also includes other Theoretical Framework such as Activity Theory, Bloom's Taxonomy, Technology Acceptance Model and highlights the threading of theories in this research. A thorough discussion about Research Design and the strategies adopted in this particular research is elaborated in this chapter.

CHAPTER FOUR (Presentation of the SMART Learning Environment): This Chapter discusses the underlying architecture, design, algorithms used, technology used, implementation strategies and Testing of the SMART Learning Environment. The chapter will break down the DSRM showing the various stages and how it has been used to drive the conception of the SMART Learning Environment.

CHAPTER FIVE (Presentation of Survey Results and Discussion): This Chapter describes the results obtained following survey carried out with a sample of the ICT Professionals in Mauritius. A description of the research methods and instruments used will be outlined. This chapter will also deal with data analysis as well as the reliability and validity of the research methods used. Ethical issues considered during data gathering will also be discussed. This chapter also critically analyses the results obtained.

CHAPTER SIX (Conclusion, Limitations and Future Research) present the main findings of the research, conclusions and the pertinent recommendations on the basis of the findings. Relevant recommendations are made. Limitations to the study are also mentioned.

1.13 Chapter Summary

This chapter gives an insight of the research under investigation by presenting an introduction and a background of the problem. The problem statement was further investigated by elaborating the research questions. The relevance of this research in the researcher's local context has also been emphasized. This chapter also outlines the scope and delimiters of the research being carried out. A research blueprint has been elaborated. Finally the structure of the thesis is presented. The next chapter (Chapter Two) provides a review of pertinent literature pertaining to the study with a focus on technical issues pertaining to the design and implementation of SMART Learning Environments.

CHAPTER TWO: LITERATURE REVIEW

"We must never forget our teachers, our lecturers and our mentors. In their individual capacities have contributed to our academic, professional and personal development."

— Lailah Gifty Akita, Pearls of Wisdom: Great mind

2.1 Introduction

Teaching and Learning have evolved as there have been opportunities offered with the advent of new technologies. Sharing and delivery of information and knowledge is more accessible and easier, particularly with new means of communication technologies, thus creating opportunities in education (Büyükbaykal, 2015). There is an academic revolution in the world of education, where both technology and education have intersected to create a digital revolution (Collins and Halverson, 2018). e-Learning provides a wide range of means in the form of computer-based learning, web-based education, social network learning platform, multimedia learning and online learning, amongst others, to deliver instruction and to increase its accessibility (Moore et al., 2011; Ruiz et al., 2006; Dringus & Cohen, 2005; Triacca et al., 2004; Khan, 2001; Govindasamy, 2001; Wagner, 2001). Researchers (Baran, 2014; Ross et al., 2010) found that using technology in teaching and learning, motivates learners and keeps them engaged in learning as well as encouraging their integration in the classroom.

2.2 Technology Enhanced Learning: Origins, Developments and Future Directions; perspectives from the analysis of a century's transition

The origins of Technology Enhanced Education dates back to the 1920's where the radio was used to teach through broadcasted classes. In the 21st century, the use of social media in education became popular. Dabbagh and Kitsantas, (2012) highlights that the integration of social media for academic purposes, is creating new ways of teaching and learning, thus leading to e-Learning 2.0. The change in e-Learning further evolves during the 21st century, to the development of Massive Open Online Courses (MOOC). McAulay et al. (2010) describes MOOCs as "an online course with the option of free and open registration, a publicly shared curriculum, and open-ended outcomes". MOOCs have gained a lot of popularity due to their efficiency in knowledge distribution and scalability (Kizilcec et al. 2013; Kim et al. 2014; Gaebel 2017). Learners normally enrol on MOOCs to increase their knowledge or to learn a topic of interest and the duration of the course can run from hours to months. The last five years has also witnessed an increase in the processing power of computers, the ability to store massive amount of data and a definite boost in the speed of network connections. This has led to the emergence of new concepts and technologies, which were previously not possible. Examples include Mobile Computing, Cloud Computing, Big Data, Learning Analytics, Computational Intelligence, Data Mining, Artificial Intelligence, Agent Based technology, Sensor Technology, Internet of Things (IoT), Augmented Reality (AR), Sematic Web, just to name a few. All this is having a deep impact on our way of living. Technology Enhanced Learning which depicts learning in this digital age is gaining increased attention. The idea is why not use this plethora of new technologies to make teaching and learning process more effective, efficient and engaging (Merrill, 2013).

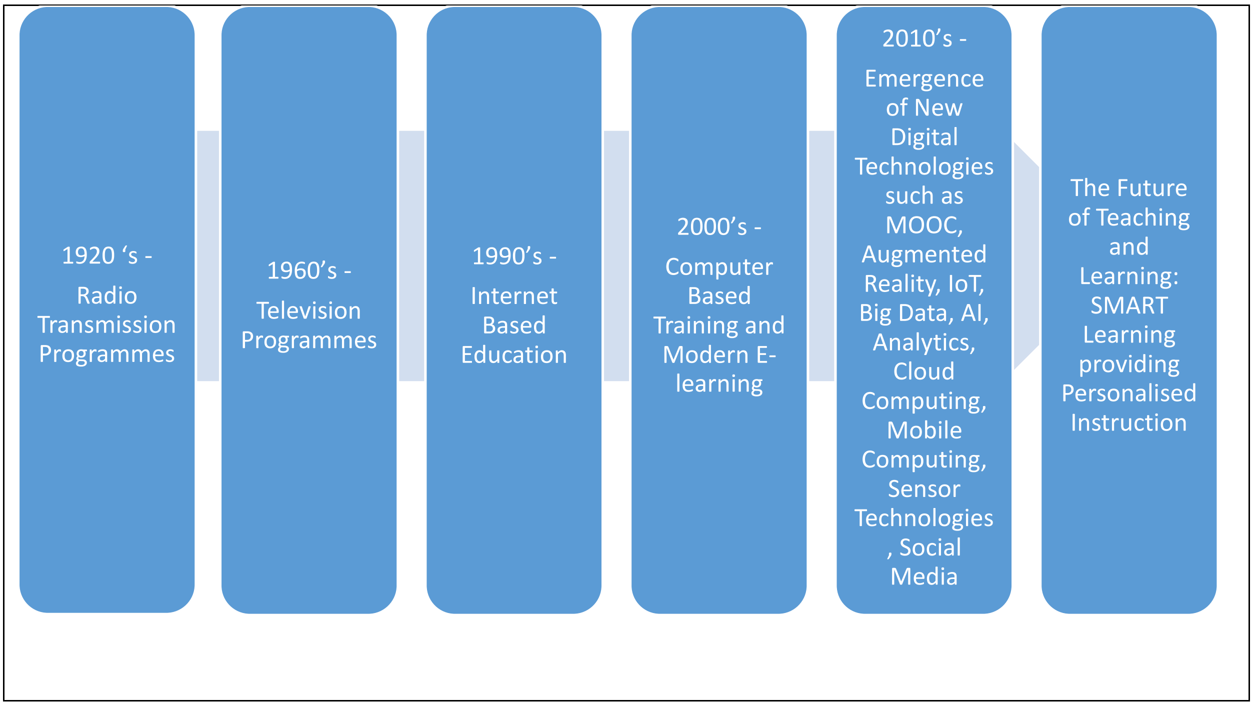


Figure 2. 1: Evolution of a century's teaching and learning process

(Source: Adapted from Rajaballee, 2018)

The table below compiles some of the available references to justify the researcher's point of view to justify the evolution of a century's teaching and learning.

Table 2. 1: References justifying researcher's viewpoint of the evolution of teaching and learning.

(Source: Adapted from Rajaballee, 2018)

Technology	References
Radio transmission programmes	Bates, 2005; Bower and Hardy, 2004
Television Programmes	McKune, 1966 ; Johnson, 1988; Schlosser and Anderson, 1994; Bates, 1985
Internet Based Education	Kock, 2001; Smyth, 2005.
Computer-based Training and Modern E-learning	Cross, 2004; Sheridan et al., 2002; Dalsgaard, 2006; Rouse, 2011; Gotschall, 2000; Zahm, 2000; Karon, 2000
Emergence of New Digital Technologies	Dabbagh and Kitsantas, 2012; Kumar et al., 2011; Downes, 2010; McAulay et al. 2010; Brahimi and Sarirete, 2015; Kizilcec et al., 2013; Kim et al., 2014; Gaebel, 2017; Merill, 2013
SMART Learning Environments	Sung, 2015; Jang, 2014; Zhu et al., 2016; Koper, 2014; Spector, 2014; Hwang, 2014; Dron, 2018; Freigang et al., 2018; Peng et al., 2019; Ha and Lee, 2019.

2.3 Technology Enhanced Learning in the Republic of Mauritius

Mauritius has been using Technology in Education since the last 20 years through a number of initiatives and projects. The University of Mauritius through the Centre for Professional Development and LifeLong Learning (CPDL) has played a pioneering role locally, in the early 2000's through teaching and learning carried out through Distance Education and E-learning. The Mauritius Institute of Education (MIE) has also contributed greatly through a number of initiatives to promote Digital Education. One of them is the Sankore Project launched in 2008 which aimed at the digitalisation of the Mauritian classrooms through the use of interactive whiteboards and a platform for the exchange of digital learning contents. At the national level, the Government of Mauritius has spearheaded a number of projects which aimed at empowering the citizens with the necessary skills for digital learning. The Internet and Computing Core Certification Program (IC3) has been trained a significant portion of the population since its inception in 2007 and has taught the basic skills required for an online learning environment to the mass. More recently, during the last two years, the Government of Mauritius has also introduced the Early Digital Learning Programme (EDLP) through the introduction of Tablets in Grade 1&2 classes (primary level schooling). This has been introduced in view of creating smart classrooms and to provide to the digital natives a new culture of learning driven by e-learning and e-pedagogies. While fostering so much efforts in training the mass for IT Literacy and an exposure to digital learning environments (through the IC3 program) and the education of our digital natives (through the EDLP), have we not created a gap in terms of training needs for professionals in Mauritius, especially as far as IT is concerned?

2.4 Challenges in the field of Technology Enhanced Learning (TEL)

The emergence of all these new technologies in the educational arena is interesting but the real challenge lies in the learner's need rather than the technological possibilities. It should not be forgotten that the learner is at a centre of the learning process and using these technologies in a disparate fashion will not be helpful to the learner. The benefits of using e-Learning are immense and unquestionable. However, e-Learning courses also present higher dropout rates due to the fact that distance education may create a sense of **isolation** in students, who can feel disconnected from the other students, the instructors and the teaching and learning process in general (Juan et al, 2009). If we consider the example of MOOC, which has been depicted as a definite potential to open up educational opportunities, yet what is observed is that the retention rate is very low, dropout rate very high and the completion rate is only around 13% (Onah et al, 2014; Hone and El Saib, 2016). Very often there is a lack of commitment and involvement of the learners on MOOCs (eg Coursera and edX) since they feel that they are learning materials either too easy for them or too difficult or not at all adapted for them. Eventually the learners get totally 'disconnected' from the learning process and this results in a drop-out from the course.

Contemporary e-learning and web-based instruction also have a major limitation. The current teaching and learning system adopts the concept of **'one-size-fits-all'** where it is expected that all learners are equal and learn in the same way; which is definitely not true. Atman et al (2009) argues that individuals have different backgrounds, preferences and motivation in their own learning preferences and Web-based systems that ignore these differences have difficulty in effectively meeting learners' needs. Levy (2008) discusses that learners all have different abilities, learning styles and personalities and that educators are mandated to see that all the learners meet and even exceed the learning standards and outcomes initially set. Levy (2008) proposes to use differentiated instruction strategies through differentiated content, process and products for the different types of learners but does not explain how this can be achieved through the use of technology. Technology can be used to provide differentiated instruction is discussed by Neti (2018), Vice President of IBM Watson Education where he highlights that with the use of Artificial Intelligence as an added assistant, the goal of IBM is to encourage lifelong learning where each person will have access to personalised learning contents that will help them succeed in the school and beyond.

Different lifelong learners have different styles and progress differently through the learning process. Learners are not equal and have differences and/or may evolve in different environments / context. These differences can be classified as Intrinsic or Extrinsic. Intrinsic context whereby the learner's cognitive factors (for example prior knowledge, pace of learning, learning style, cultural background, preferences) are considered and extrinsic factors where the learner's immediate environment are considered (for example, availability / presence of a good internet connection). So the main problem that is encountered and that needs to be addressed is the lack of personalisation in our teaching and learning process.

The problem with traditional web-based learning is that very often there is a lack of commitment/involvement of the learners. There is a strong feeling that the learning materials are either too easy for them or too difficult or not adapted for them and/or they do not have necessary extrinsic factors (for example good internet connection and/or necessary devices for learning). This lack of personalisation of learning materials is seen as a major problem and this has been confirmed by a number of researchers and research in this direction is progressing slowly but surely (Zhu et al., 2016; Sung, 2015; Jang, 2014). Furthermore, the traditional learning process does not encourage the learner to go to a higher cognitive level. Indeed learners for the 21st century have to be trained by promoting their problem-solving capabilities instead of just passively assimilating learning content.

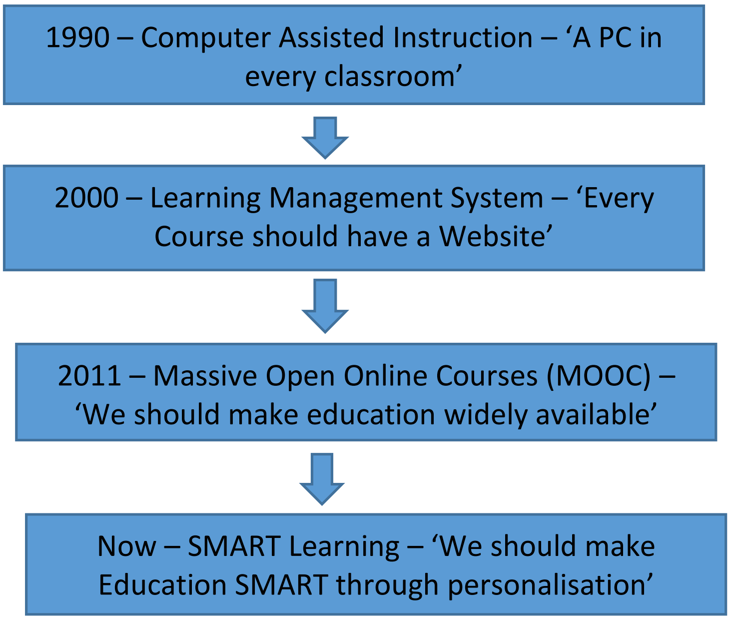


Figure 2. 2: Evolution of ICT in Education

(Source: Researcher's own construction)

So the way forward in teaching and learning in this Knowledge Society is one whereby a holistic approach is adopted and where the learner's imagination, creativity and motivation is going to be sparked. It is for sure that learning of the future will be connected and one that best reveals the opportunities and possibilities inherent in the use of Digital Technologies, especially as the concept of personalised learning emerges. The future of education and training is seen as one whereby SMART Learning is used to ensure that the teaching and learning process is made interesting, motivating, effective and above all personalised according to the learner's needs.

2.5 Learning Environment

The word Learning Environment can be of different meanings and can be used in different contexts (Abualrub et al. 2013). One interesting definition of Learning Environment is provided by (Glossary, 2014) where it states that "Learning environment refers to the diverse physical locations, contexts, and cultures in which students learn" and also adds that Learning can take place in a number of settings besides the traditional classroom, which has limited and traditional connotations. Learning Environments can include classrooms, labs, natural sites, museum and workplaces just to name a few. Most Learning Environments are suited to stimulate learning towards some learning objectives by complementing with learning materials, tasks to be completed, tests, feedback and support (Koper, 2014).

2.6 SMART Learning

Jang (2014) describes SMART Education as "**Self-directed, Motivated, Adapted, Resource-enriched, and Technology-embedded**". These characteristics imply that smart learning extends educational time, methods, competencies, contents, and spaces (Sung, 2015). **Self-directed** depicts the change of role of learners from being passive receptors of knowledge to generators/contributors of knowledge and teachers moving from being disseminators of knowledge to a role of mentor. **Motivated** highlights the means in which SMART Education will encourage the learner to take interest in the learning process, changing from typical textbook-based to experienced-based learning, thereby triggering the learner's creativity and engagement. The concept of engagement is further discussed in this section and is perhaps one of the major reasons accounting for the high drop-out rate in MOOCs. **Adapted** goes in line with the concept of personalisation and customisation of teaching and learning processes and learning contents, bearing in mind that all learners are different. **Resource-enriched** extends the educational content by facilitating various educational resources. For example, resource-enriched learning environments can provide open-educational resources and materials delivered through a cloud that ensures safe upload and download and readily available to learners and teachers. **Technology-embedded** illustrates the use of the latest ICT technologies in the teaching and learning process, facilitating the latter to a great extent. This can allow for anytime and anywhere learning anytime, thereby promoting ubiquitous learning.

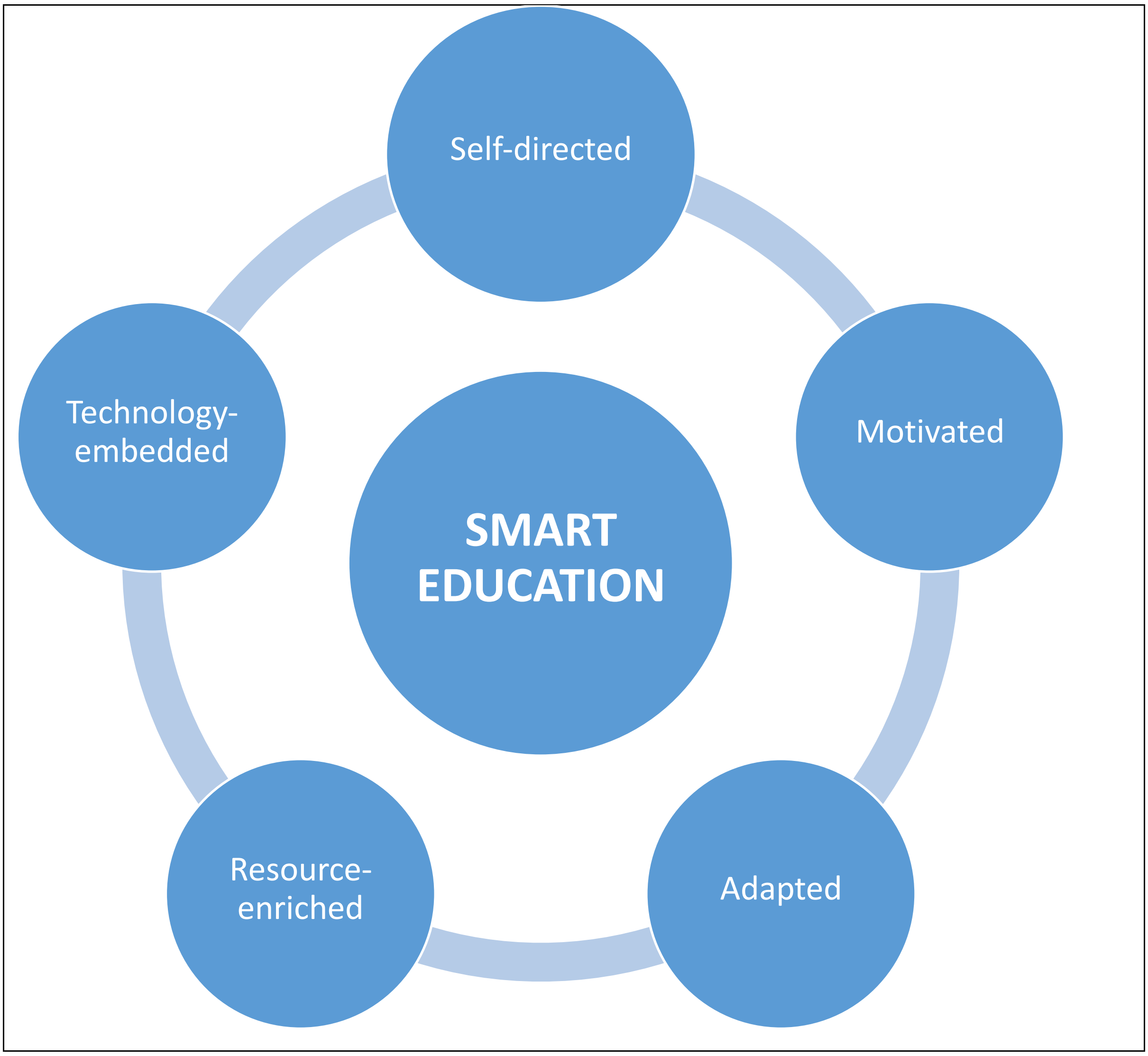


Figure 2. 3: SMART Education

(Source: Adapted from Jang, 2014)

Zhu et al. (2016) argues that there is no clear and unified definition of SMART Learning so far but it can be said that this SMART Learning Environments are seen as a whole ecosystem of Technology and Pedagogy with the active participation of learners and teachers. SMART Learning environments could eventually decrease the learner's cognitive load so that the latter can focus on sense making and facilitate ontology construction (Zhu et al, 2016). Hence the learner's learning experience can be deepened and extended.

The approach to teaching in Smart Learning Environments provides a customised service to adapt to the individual needs and level of each student. In conventional public education, it is usually difficult to teach students individually. **Tailored learning** is the main strength of Smart Learning, and communication with tutors continuously improves students' motivation for learning (Kim et al, 2012). Personalisation of learning materials can be seen as a viable alternative instead of providing same learning materials for everyone. Personalisation of learning materials can be done with the use of adaptive learning systems whereby the preferences and individualities of the learners would be considered. Adaptive learning may be referred as the process of creating unique learning experience for each and every learner based upon the learner's personality, interests and performance in order to achieve goals such as student academic improvement, learner satisfaction, effective learning process and so forth (Yaghmaie and Bahreininejad, 2011). Research studies consistently show that students achieve significant learning gains when using adaptive systems, which includes intelligent tutoring systems (ITS) (Dodds and Fletcher 2004; Durlach and Ray 2011; Ritter et al. 2007; VanLehn 2011). Robson and Barr (2013) though acknowledging the benefits of having SMART Learning Environments and Intelligent Tutoring Systems, discusses that this remains restricted to research projects and there is only a few commercial applications. Munnerley et al. (2012) argues that learning should be liberated from traditional spaces such as classrooms, lecture theatres and labs and should instead envelop the students wherever they are.

2.7 Comparison between Context-Aware u-learning, Adaptive Learning and SMART Learning

The terms Context-Aware u-learning, Adaptive Learning and SMART Learning are at times used interchangeably and a comparison of these terms are deemed important to fully understand the differences, which at times can be subtle. Nowadays there has been rapid progress in the field of wireless, mobile and sensing technologies. This has led to the emergence of context-aware ubiquitous learning environments referred to as **u-learning** environments (Hwang, 2014). U-learning Environments are able to detect real-world learning status and environmental contexts of learners. Accordingly appropriate information can be provided to the learner at the right place and at the right time. An

adaptive learning system is developed for supporting students to probe and acquire knowledge based on their learning status and personal factors, such as learning progress, knowledge levels, learning styles, cognitive styles and preferences (Mampadi et al., 2011; Papanikolaou et al., 2002; Yang et al., 2013a,b). Due to the popularity of the World Wide Web, many researchers have attempted to develop adaptive learning systems on the web. These adaptive learning systems are known as Adaptive Hypermedia Learning Systems or Adaptive Educational Hypermedia (Specht et al. 1997 and Chen at al. 2012). The concept of SMART Learning has been discussed in the previous section and the table in Annexure B summarises the major differences between SMART Learning, u-learning and Adaptive Learning.

2.8 Related Works on SMART Learning Environments

Developing SMART Learning Environments is at this stage still predominantly being done in Research Institutions and rarely for commercialization purposes (Yau and Joy, 2017). The learner is always considered to be as the focal point of the SMART learning environments and the rationale is to be able to provide self-motivated, self-learning and personalized services whereby the learners can attend courses at their own pace and are able to access the personalized learning content according to their personal circumstances (Kim et al. 2012). Koper (2014) suggests that SMART learning environments can be seen as physical environments that are enriched with context-aware, digital and adaptive devices, to promote faster and better learning. Spector (2014) describes a SMART Learning as one that is engaging, efficient and effective. Hwang (2014) suggests that an interesting feature of a SMART learning environment may include context-aware services that are able to offer instant and adaptive support to the learners. The necessary learning guidance is here seen as a very important component of the SMART Learning Environment. The section that follows describes some of the past attempts to implement SMART Learning Environments. The inherent limitations and the challenges encountered are also critically analysed.

2.8.1 Two-Source Adaptive Learning (TSAL) (Tseng et al, 2008)

Tseng et al (2008) proposed an Intelligent Tutoring Environment having personalisation carried out in two phases as described in its two-source learning (TSAL) component. Firstly, it monitors the student's learning styles and secondly the student's learning behaviours. This differs from previous Adaptive Learning Systems which mostly used only one source of data to provide personalisation. The different learning styles and learning behaviours used in the research of Tseng et al. (2008), are summarised in Figure 2.4. TSAL allowed instructors to create adaptive learning materials for science courses. The results of experiments carried out show that providing adaptive learning materials to the learners helped to enhance the learning efficacy and improve learning achievements (Tseng et al., 2008). The challenge, however, remained that multiple versions of the learning materials had to be created to suit the different categories of personalisation information obtained. A modular approach was adopted and the architecture of TSAL is shown in Figure 2.5.

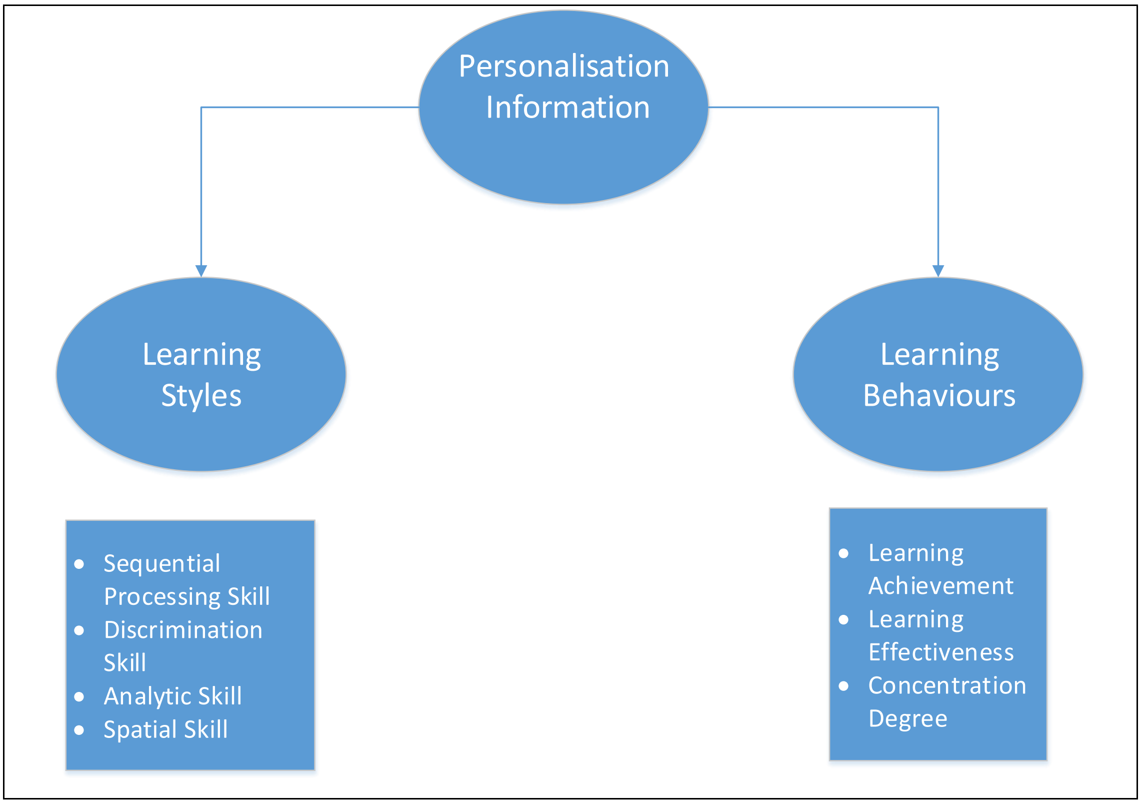


Figure 2. 4: TSAL Features

(Source: Adapted from Tseng et al., 2008)

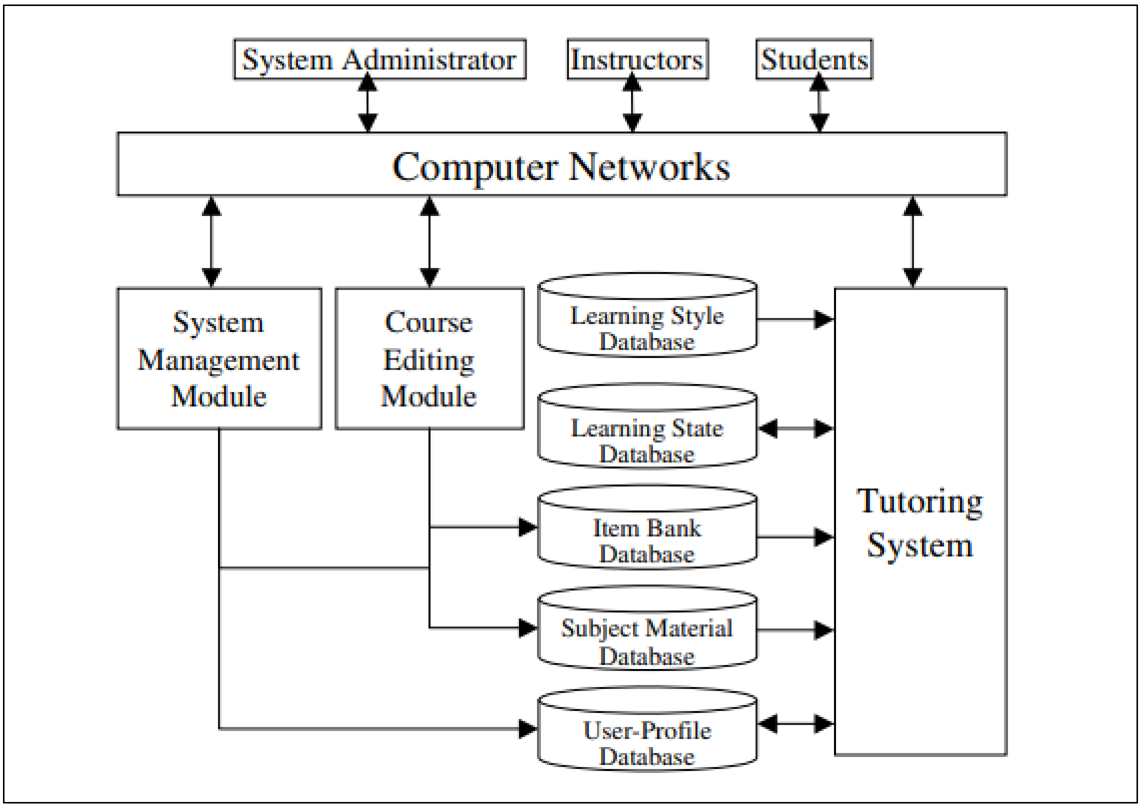


Figure 2. 5: TSAL Architecture

(Source: Adapted from Tseng et al., 2008)

2.8.2 Intelligent learning system with personalized learning path guidance (Chen, 2008)

Chen (2008) proposed an intelligent learning environment which utilizes a genetic-based algorithm to construct the personalized learning path which focuses on the level of difficulty of the course and at the same time, the learning process. Moreover, this algorithm generates suitable learning paths according to the incorrect answers of a student in a test. Based on the marks of test, the learning system can conduct personalized syllabus sequencing through simultaneously considering the difficulty level of the course material and the steadiness of learning paths to support web-based learning. An architecture of the system is shown in Figure 2.6. The proposed system makes use of software agents. A description of Software Agents as a technique to build SMART Learning Environments is given in section 2.11.5.

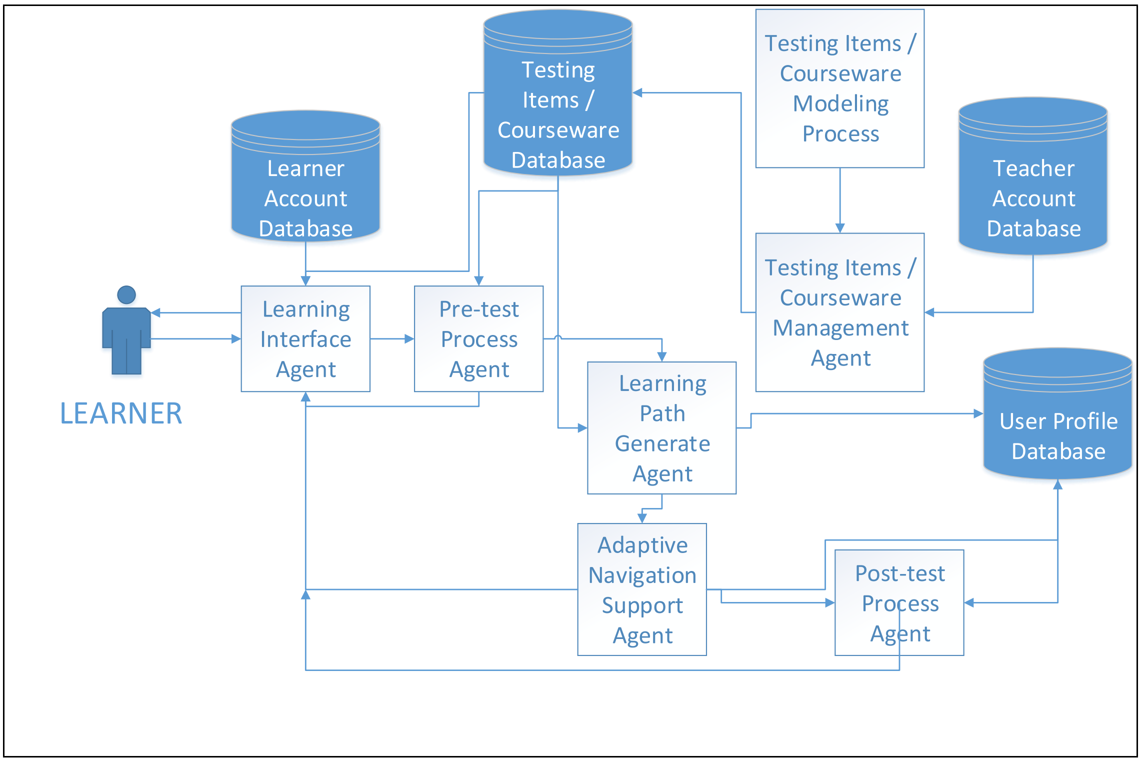


Figure 2. 6: Architecture of Genetic-Based Personalised e-learning systems

(Source: Adapted from Chen, 2008)

2.8.3 The Adaptive Learning System based on Learning Style and Cognitive State (ALS-LSCS) (Cheng and Zhang, 2008)

Cheng and Zhang (2008), depicted an Adaptive Learning System based on Learning Style and Cognitive State. This adaptive learning system focuses on the traits of the learner's personality, like for instance the style of learning and allows teachers to monitor the learning phase of the students. The learning style is determined through the use of Felder-Silverman's categorisation, which includes the following learning style categories; (i) Sensing v/s Intuitive Learner (ii) Visual v/s Verbal Learner (iii) Active v/s Reflective (iv) Sequential v/s Global.

The Felder-Silverman's categorisation is described in more detail in section 2.14. The cognitive state of the learner is captured through a multi-layered overlay model which takes as parameter several factors such as whether the learning material has been visited, whether the learner has finished the concept to be studied and whether the learner has taken part in adaptive tests. Both the learning style and cognitive state captured, thereafter enabled the construction of a learner model which is dynamically updated as and when learning takes place. Besides the learner model, the proposed system by Cheng and Zhang

(2008) also consists of several other components such as Media Space, Domain Model, Instruction Model, Adaptive Model and the User Interface. The architecture of the system is based on 'A Reference Model to Support Adaptive Hypermedia Authoring Model' (AHAM model) and is shown in Figure 2.7 below.

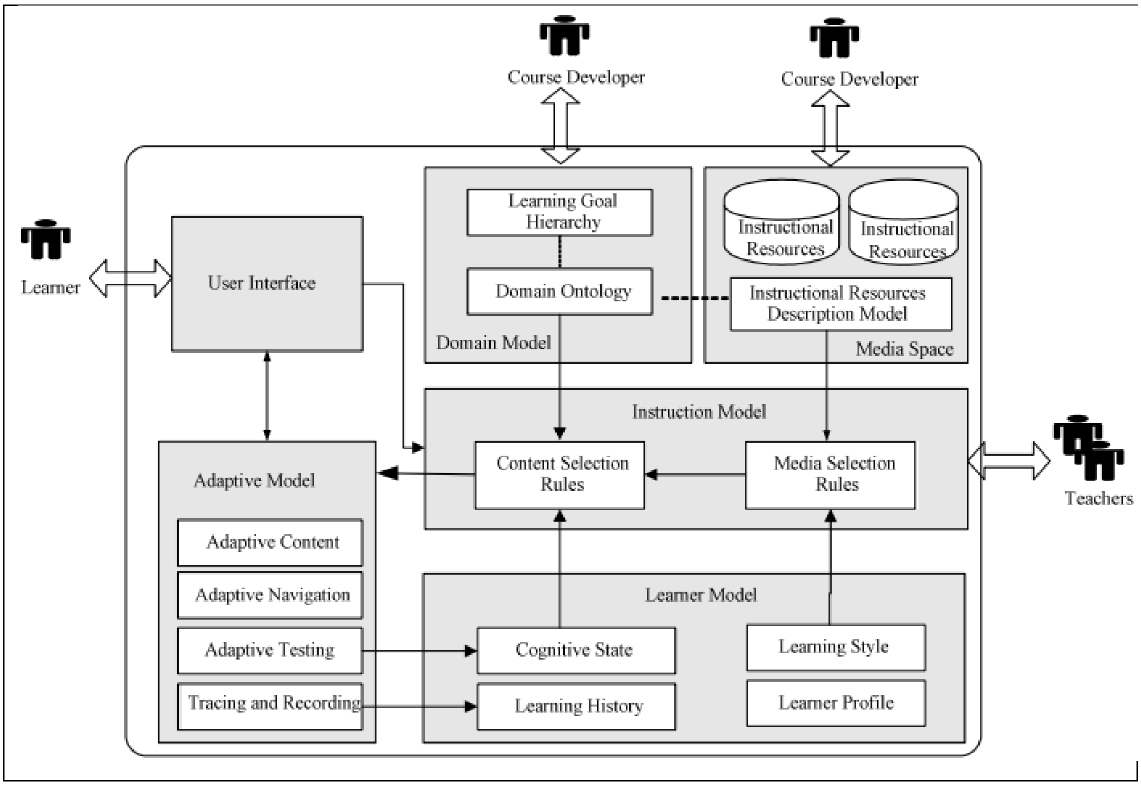


Figure 2. 7: Architecture of ALS-LSCS

(Source: Adapted from Cheng and Zhang, 2008)

The proposed system encourages collaborative learning and 'learning by doing'. Another interesting aspect is the reuse of domain knowledge and the use of Domain Ontology which is built around knowledge components and their relationships.

2.8.4 Intelligent, Adaptive learning or Tutoring System (IATS) (Gowri et al., 2011)

In another study, Gowri et al. (2011) put forward an adaptive learning tutoring system that uses agent based technology. Further description of Agent-Based systems is given in section 2.11.5 of this thesis. The proposed system model was developed using the Organization-based Multiagent Software Engineering (O-MaSE) development approach model which basically allows for custom agent-oriented processes to be designed by using a set of method fragments. To accomplish this, OMaSE was defined in respect to a Meta model, a set of guidelines and a set of method fragments. The OMaSE Meta model specified a set of analysis, design and implementation approaches whereby each set has a set of constraints. The adaptive behaviour of the system was achieved by grouping together all the similarities between the student such as their skills, learning styles and other criteria. Using this method, the course contents of each user were displayed to them according to their position in the clusters. The clustering was done using the Fuzzy C-Means algorithm which allows data to belong to multiple clusters. A further description of Fuzzy Logic is given in Section 2.11.1 of this thesis. To represent the content of the course, a tree like structure was constructed and whereby the student was at certain level of the course, only the content which corresponded to that tree would be displayed to the student. The learning materials are further categorised as HTML, audio, video, flash or any other combination of these types.

2.8.5 Context-Aware and Adaptive Learning Schedule (CALS) (Yau and Joy, 2017)

Yau and Joy (2017), developed a tool for new computer science students at the university level to help them to learn the Java language effectively. The Context-Aware and Adaptive Learning Schedule (CALS) provided the students with appropriate learning content and available time and location based on the student's daily activities which they had to input. The tool consisted of five main components which are described below.

1. **Learner Schedule** for capturing and scheduling learner activities.
2. **Learner Profile** for storing learner preferences.
3. **Learning Object Repository** where the learning materials are stored.
4. **Learning Profile Adaptation** module which provides adaption in different forms. This is delivered by three sub-modules, namely Learning Priorities adaptation, Learning Style adaptation and Knowledge Level adaptation
5. **Context-Aware Adaptation** Module which provides adaptation based on the learner's location and time s/he is available.

The architecture of the system is shown in Figure 2.8. The learner is responsible for inputting accurate information, in terms of scheduled events and learning preferences.

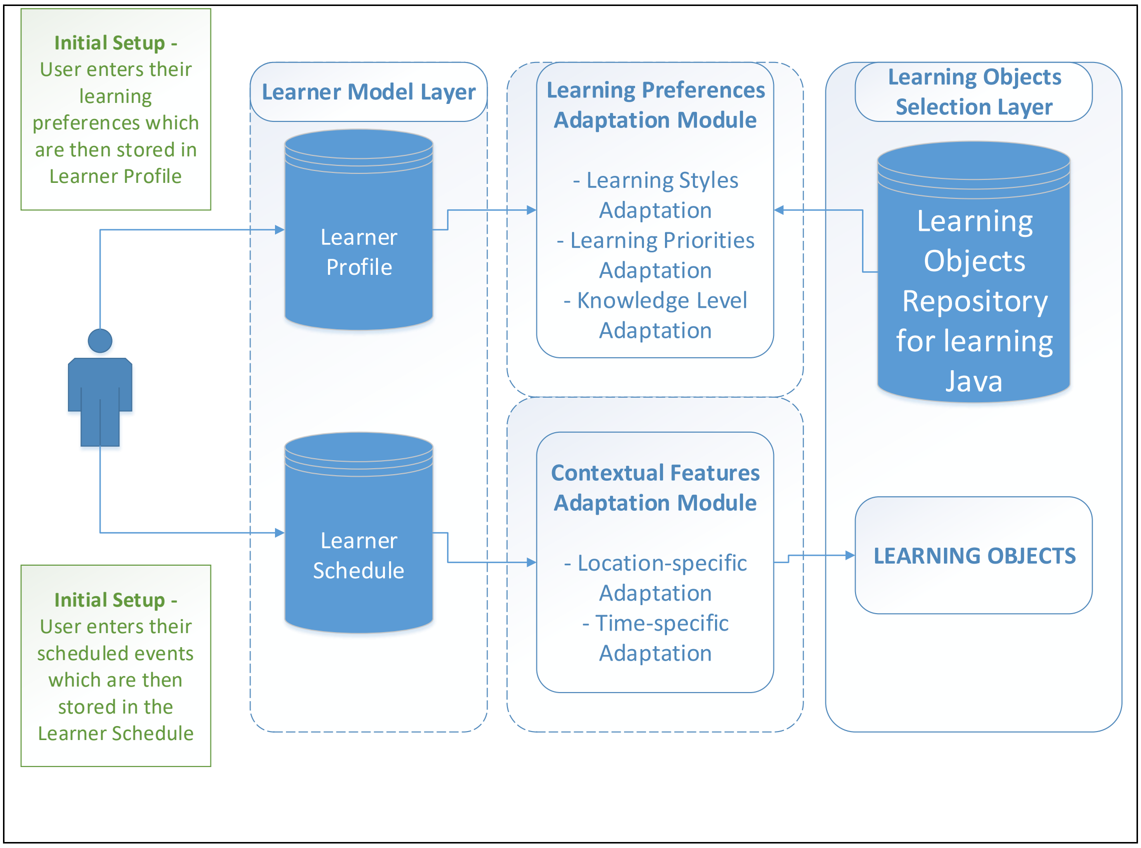


Figure 2.8: System Architecture of CALS

(Source: Adapted from Yau and Joy, 2017)

The system also depicts some interesting features such as the ability to measure the noise level through a sensor and to be able to determine the level of concentration accordingly.

2.8.6 Data mining for adaptive learning in a TESL-based e-learning system (Wang and Liao, 2011),

Wang and Liao (2011) proposed using **A**daptive **L**earning for **T**eaching **E**nglish as a **S**econd **L**anguage (AL-TESL) in Chinese Taipei. A data mining technique, Artificial Neural Network (ANN) using the back-propagation (BP) algorithm was used to construct the system. ANN comprises of processing elements namely: nodes, neurons and the connections. The nodes are related layer-wise. The BP algorithm uses a neural network of layers, that is, the input layer, the hidden layer and the output layer. A thorough description of the concept of Artificial Neural Network is given in section 2.8.3 of this thesis. Three different levels of teaching for grammar, vocabulary and teaching was used in the research of Wang and Liao (2011). The learner is prompted to enter information about his personality type (introverted = 1, mildly introverted = 2, neutral = 3, mildly extroverted = 4, and extroverted = 5) and his/her level of anxiety (high anxiety = 1, moderate anxiety = 2, and low anxiety = 3) and gender. This research explains that student anxiety pertaining to the learning of a foreign language can be viewed from three perspectives; anxiety related to tests, communication apprehension and fear of negative feedback and evaluation. The system also highlights that different learning paths are able to accommodate the differences and needs of each learner. Learners using the AL-TESL were then evaluated and compared with other learners who were using the conventional way of teaching, which involved delivery in a regular online course. Results show that learners using the AL-TESL performed much better. The researchers also argue that one major obstacle for the development of such adaptive learning system is the high cost for developing learning materials in Taiwan. This research also presents adaptive learning as a means for promoting learners' motivation and puts forward that future works can include the use of such systems for the training of disadvantaged learners or for continuing education.

2.8.7 Alta Adaptive Learning Technology (Knewton, 2020)

Alta Adaptive Learning Technology (Knewton, 2020) is an example of a personalised learning environment that has been put on the market by Wiley. Alta is a web learning platform which focuses on adaptive sequences and provides a fully integrated courseware. It records feedback and responds to changes on a real time basis. Accordingly, the learning materials are built on thousands of observations consisting of theories, structure, and difficulty level. Alta analyses these learning materials and uses sophisticated algorithms to render the most appropriate content to the user. The developers of Alta also argue that data is collected from a network of students and this data is recorded, analysed and applied to optimize the next output for each student (Knewton, 2020). Alta promotes the concept of Adaptive Learning and argues that its main strengths lies in (1) Dynamic and ongoing remediation that encourages just-in-time learning (2) Instructor Control and (3) Student Responsiveness. The major weakness of using Alta as a case-study for this research is the complete opacity as far as its development architecture, technology and processes are concerned. This can be attributed to the fact that Alta is a commercial product.

2.9 Critical Discussion of Current Research in the area of SMART Learning

Having examined the design and conceptualisation of SMART Learning Environments, a critical discussion of the above is deemed to be important by the researcher. The interesting features and inherent limitations of each of these systems are discussed in the table below.

Table 2. 2: Comparison of existing systems in the area of SMART Learning

(Source: Researcher's own construction)

System	Strengths	Weaknesses
1. Two-Source Adaptive Learning (TSAL) (Tseng et al, 2008)	• Two-source personalisation (learning behaviour and learning style) • Presentation of learning materials with different levels of difficulty • System developed using a modular approach	• The concept of using Learning Style is debatable and has been criticised by numerous researchers, including (Newton ,2015); Newton and Miah, 2017; Singal, 2015; Goldhill, 2016) • The major limitation lies in the need to develop six versions of learning materials to meet personalization requirements • With the advances in the field of Artificial Intelligence, a more effective means of

		providing personalised learning materials can be envisaged.
2. Intelligent learning system with personalized learning path guidance (Chen, 2008)	• Use of AI-related techniques, more specifically the use of Genetic Algorithms and Intelligent Software Agents which bring a new dimension to the concept of personalisation • Use of Sharable Content Object Reference Model (SCORM) which helps towards the standardisation of learning materials.	• The application is completely in Chinese with no translation possible. • Lack of feedback to the learners. • Visualisation to see learner's progress is not available.
3. The Adaptive Learning System based on Learning Style and Cognitive State (ALS-LSCS) (Cheng and Zhang, 2008)	• The system positively considers the different stakeholders in the learning process. • The research presents an interesting approach to learning style by using the Felder-Silverman's	• This research does not give any insight about the effectiveness of the adaptation taking place • Proposed system is limited in the sense that it appears to be only a framework which has been developed.

	learning style categorisation. • Encourages 'learning by doing' • Makes use of Domain Ontology and encourages reuse of Knowledge Domain	
4. Intelligent, Adaptive learning or Tutoring System (IATS) (Gowri et al., 2011)	• Use of AI-related techniques such as Agent Technology, Clustering and Fuzzy Logic. • The learning materials are presented in different formats including audio, video, HTML and flash. • The system is developed using a well-defined process, namely Agent Oriented Software Engineering which gives it a certain industry acceptance and credibility.	• No provision is made for learning materials in the form of large video file size. Video files need to be split for effective storage and retrieval • No experiment / testing is done to determine the degree to which the system is effective in providing adaptive behaviours for different learners.
5. Context-Aware and Adaptive Learning	• System is developed using a modular	• The onus of inputting accurate

Schedule (CALS) (Yau and Joy, 2017)	approach and has a number of modules. • Features such as the ability to measure the noise level through a sensor and to be able to determine the level of concentration accordingly.	information in the system lies on the learner. • It also appears that the amount of information to be input in the system such as preferred learning style, location, time available, and others may be time-consuming • The learner might enter incorrect information for example incorrect learning style
6. Data mining for adaptive learning in a TESL-based e-learning system (Wang and Liao, 2011)	• This research attempts to bring adaptive learning to a completely new domain which is the teaching of English as a secondary language • The comparison of an experimental sample of learners using AL-TESL with a sample of 'normal learners' reinforces the	• The information that the learner is expected to input (personality type, level of anxiety) is highly subjective and if not correctly input in the system, will lead to incorrect output. • The learning materials to be developed in this context proved to be very costly

	statement that one-size-fits-all learning is not motivating and fruitful.	
7. Alta Adaptive Learning Technology (Knewton, 2020)	• Dynamic and ongoing remediation that encourages just-in-time learning • Instructor Control • Student Responsiveness.	• Complete opacity as far as development architecture, technology and processes are concerned

SMART Learning environments provide a number of benefits as compared to traditional technology-enhanced learning. As demonstrated by previous research (Tseng et al, 2008; Chen, 2008; Cheng and Zhang, 2008; Gowri et al., 2011; Yau and Joy, 2017; Wang and Liao, 2011; Knewton, 2020), personalisation of contents, different learning pathways for learners, customised guidance and feedback are some of the interesting features of SMART Learning Environments which greatly contribute to make the learning process more effective, engaging and enriching. On the other hand, the development process of SMART Learning Environments appears to be complex, requiring a deep understanding of AI-related concepts and other related technologies. The final choice of the technologies used for this study was determined after a thorough analysis of the different options as seen in section 2.11 below. Yet another challenge remains in bringing the concept of SMART Learning Environments beyond the so-far experimental and academic setting to a more applied and real-life scenario, which is that of the training and up-skilling of Cybersecurity Professionals in Mauritius.

So far, what is also seen is that SMART Learning Environments have been restricted to mostly research in academia and to very few commercial products. The inherent features of SMART Learning Environments also make it suitable for learners with a certain degree of maturity who can learn by themselves and who would like to feel in control with their learning process. So far, researches and conceptualisation of SMART Learning Environments have not reached out to working professionals who are in need of constant up-skilling or reskilling. The idea of using SMART Learning Environments to address the problem identified in the previous section of this thesis is appealing.

2.10 SMART Learning Environments: Personalisation and Adaptation from different contexts

Byun and Cheverst (2004) argues that information about Places, People and Things are three types of information that can be collected to describe the context and to describe these three entities, four categories of context can be put forward (Zafar and Hasan, 2014). These four categories include Identity (entity with explicit identifier), Location (spatial and geographical data), Status or Physical Context (properties distinguished by the user, for example, noise level) and Time (time of the day, month or year).

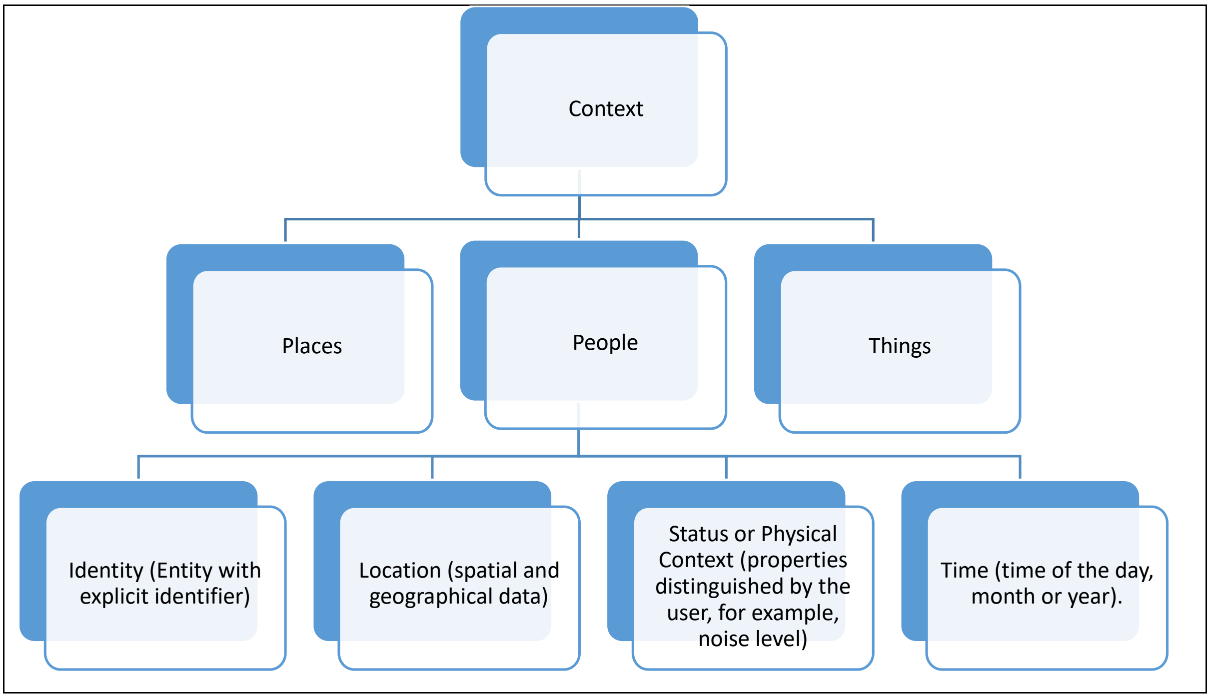


Figure 2. 9: Context influencing Learning Process

(Source: Adapted from Byun and Cheverst 2004; Zafar and Hasan 2014)

Another classification that can be used to differentiate the context, in this case, is intrinsic (internal) or extrinsic (external) factors (Dey et al, 2001; Prekop and Burnett, 2003). The intrinsic context for learning purposes may involve the learner's cognitive factors such as prior knowledge, pace of learning, learning style, emotional state and extrinsic factors may include availability of a good internet connection, necessary devices required for learning and the learner's immediate environment (for example sound and temperature level). The learner's intrinsic factors may be gathered through the learner's interaction with the learning environment whereas some of the learner's extrinsic factors such as sound level, may be collected with the use of devices and sensors.

Yet another factor, the Power Distance Index (PDI) or Power Distance Dimension plays a significant role in the way learning takes place. This is more of a societal social criteria that depicts the distribution of power and the strength of the latter among the different hierarchies of a society (Hofstede at al., 2010; Denny, P., 2012). This varies from country to country. Some countries tend to have a Small Power Distance (SPD) whereas others tend to have a Long Power Distance (LPD). A Small Power Distance (SPD) implies that there is a lower level of inequality among the different hierarchies of society and there is less of a tendency to accept the unequal distribution of power. Such countries include the United Kingdom, the Netherlands, Germany and the United States (Hofstede Insights, 2020). On the other hand, countries having a Long Power Distance (LPD) would imply that there is more of an authoritarian and autocratic structure with a centralised authority structure. In these types of society, subordination is common and subordinates are willing to accept their inferior position. Examples of countries with LPD include China and the Arab World (Hofstede Insights, 2020). The concept of Power Distance has a subtle, yet profound effect on learning and the way knowledge is inculcated. Countries with Long Power Distance (LPD) would tend to privilege an approach where the teacher is at the centre of the stage and the success of the learning process relies heavily on the quality of the teacher with approaches that are very much rigid and unquestionable. On the other hand, countries with Small Power Distance (SPD) tends to favour less formal approaches as far as the learning process is concerned and would also encourage less formal learner-teacher interactions. Here, student excellence is synonymous to the quality of the learning process that takes place (Hofstede, 1986, Lemone, 2005).

Personalisation or adaptation of learning materials can be viewed in two dimensions. One dimension is where the learning materials are seen to be personalised or customised to the individual learners and this is seen as 'adaptive presentation' and another dimension where the Learning Environment guides individual learners to find the learning materials with a personalized learning pathway creating a ‘personalised navigation support’.

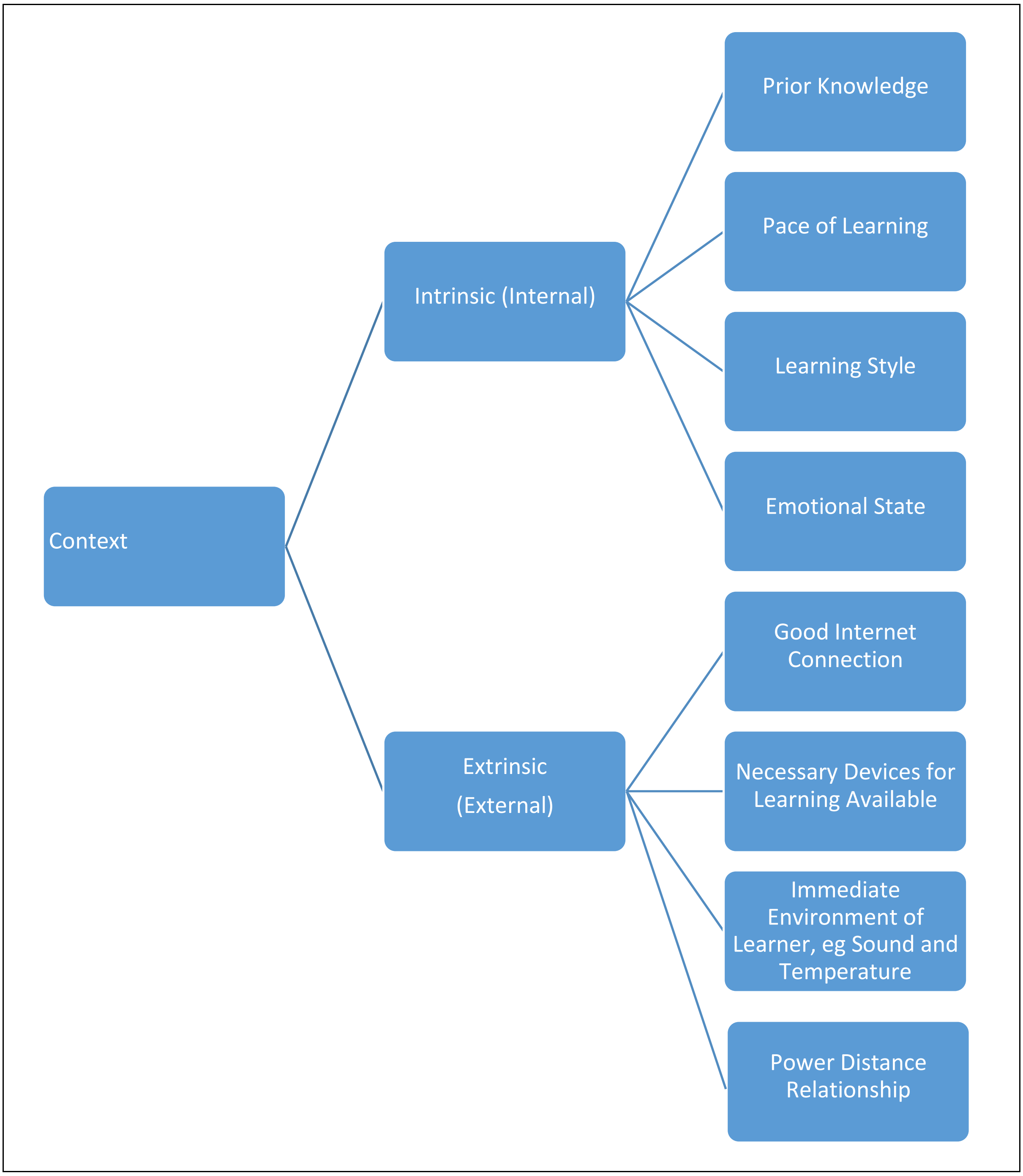


Figure 2. 10: Context influencing Learning Process

(Source: Adapted from Dey et al, 2001; Prekop and Burnett, 2003; Hofstede, 2005; Denny, 2012)

2.11 SMART Learning Environments: Techniques and Technologies

A number of techniques and technologies can be used to develop SMART Learning Environments. Some will respond to the extrinsic factors influencing the learning process of a learner whereas others can be used to address the intrinsic factors. This section touches the different possibilities with an understanding that the use of all of them to formulate the proposed SMART Learning Environment will not be feasible due to the scope of the project. However an understanding of the different techniques and technologies are important to comprehend the wide range of possibilities available to develop SMART Learning Environments providing personalisation.

Figure 2. 11: SMART Learning Environments: Techniques and Technologies

(Source: Researcher's own construction)

Some of the most promising technologies and techniques in developing SMART Learning Environments are discussed below. Depending on the context and scope of the development of a SMART Learning Environment, some of these technologies and techniques can be used in isolation whereas others may be used in conjunction with each other, so as to provide a more comprehensive SMART Learning Environment.

2.11.1 Artificial Intelligence

Humans have evolved to become Homo sapiens (man the wise) in their attempt to understand and perceive such a complex world as ours. Human intelligence can be seen as the intellectual prowess of humans characterised by the mental ability for reasoning, learning and problem solving (Colom et al., 2010) coupled with complex cognitive feats and high level of self-awareness and motivation. Intelligence is so important to us and, we, humans have spent years understanding how we actually think. Artificial Intelligence (AI), inspired from human intelligence aims to reach still further, by not only, understanding and depicting features of *intelligence* but by also building intelligent entities. AI is an umbrella term used in the Computer Science field that focuses on machines that simulate human intelligence processes including learning, reasoning and self-correction. There is little agreement to the ultimate definition of AI but the dawn of AI dates back to the 1950's when Alan Turing proposed the Turing test and the term was coined in 1956 at the Dartmouth Conference. Since then, a number of researchers have been giving some interesting definitions of AI. Huang (2018) depicts AI as a manifestation of machines that exhibit some aspects of Human Intelligence. Ma et al. (2014) describes AI as "the field of computer science dedicated to solving cognitive problems commonly associated with human intelligence, such as learning, problem-solving, and pattern recognition." Russell and Norvig (2010) makes an interesting parallel between human beings, which he describes as Homo sapiens (man the wise), whose mental capacities are essential for everyday lives and eventually depicts AI as a field which strives to build intelligent entities as well as understanding them. These three definitions above have a common convergence point which is that of building and understanding systems that have some form of intelligence.

Some researchers perceive the field of AI as full of promises, whereby significant gains can be achieved to the economy with a cascading effect on society. AI which was depicted at some point in time more like science-fiction, is now in the realm of what is possible, with the ability of providing solutions to boost productivity in practically all spheres of life. A parallel can be made as to how the steam engine or the Internet have been disruptive. The way technology has become embedded in our everyday life is having a profound effect on society and is even depicted as the Fourth Industrial Revolution. Indeed, the destiny of mankind has so far been shaped by the different Industrial Revolutions that took place and this is summarised in Figure 2.12. Today, we are living in an era where there is a convergence of the different technologies. With the advent of cyber-physical systems operated through the use of Artificial Intelligence and Machine Learning, completely new means of interaction between humans and machines can be created. The Fourth Industrial Revolution is indeed seen as full of promises whereby it is envisaged that there will be an uplift of society and humanity at large.

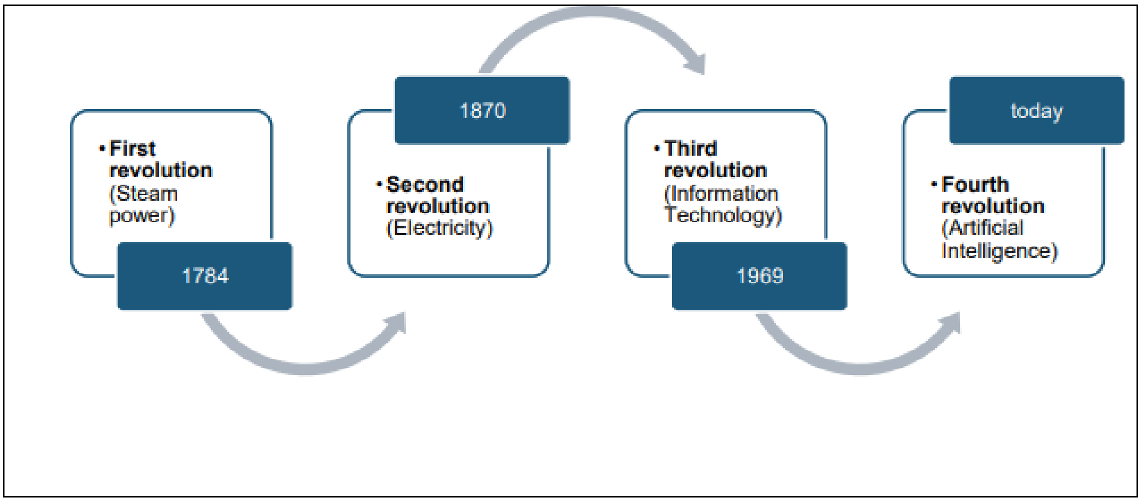


Figure 2. 12: Global Transformations

AI uses the patterns identified to create insights and knowledge that are more accurate. The hype around AI has, in the recent years, been spurred by the immense progress done in the field of technology with focus on advances in hardware and easily available software libraries for machine learning. The practical applications of AI can already be seen across numerous walks of life, from autonomous cars, Virtual Assistants, Fintech, chatbots, detection of credit card fraud, AI-powered technologies for healthcare, precision agriculture and image recognition just to name a few. AI has the ability to help students to learn at their own pace by analysing their individual learning requirements and needs. There exists a whole array of AI techniques including Fuzzy Logic, Decision Trees, Bayesian Networks, Genetic Algorithms, Hidden Markov Models (brief description given in the table below) and other AI-related concepts such as Machine Learning, Neural

Networks, Deep Learning and Agent Technology (thorough explanation given in sections 2.11.2 – 2.11.5) .

Table 2. 3: AI Techniques

Techniques	Brief Description
Fuzzy Logic	Fuzzy Logic can be depicted as an extension of multivalued logic that aims at modelling the imprecise modes of reasoning. Some view it as being helpful in situations where there is no absolute truth (Zadeh, 1988). Fuzzy logic has successfully been used in areas ranging from Finance to Earthquake Engineering.
Decision Trees	Decision Trees are very useful to build classification models which are easy to understand and an effective way of representing human reasoning. Decision trees operate in a sequential manner and combine a logical sequence of simple tests in the form of a comparison with some threshold values (Kotsiantis, 2013). If is often argued that decision trees provide much comprehensibility in the sense that it is easier to interpret as compared to models such as neural nets, which provide much opacity. This makes Decision Trees a prime choice for decision makers.
Bayesian Networks	Bayesian networks have been successfully used to model complex systems and to make diagnosis and predictions. This technique involves the computation of distribution probabilities in a set of variables. Bayesian networks are very often represented as a Directed Acyclic Graph, where the modes represent the system variables and the dependencies / cause-effect relationships represented by the arcs. The limitation of Bayesian Networks includes the fact that there is no well-defined semantic to drive the development of a coherent model (Weber et al., 2012).
Genetic Algorithms	A Genetic Algorithm is often used to solve hard optimising problems which is inspired by living beings and the theory of

	the 'survival of the fittest'. The robustness of the algorithm by giving consistent results with a broad range of problem types is perhaps one of its main advantage. Population size is an important determent of success, as a small population size may not present an adequate solution space to provide accurate results (Sivanandam and Deepa, 2008).
Hidden Markov Models (HMM)	A Markov Process or Model consists of states and fixed, known probabilities for the state transitions (Stamp, 2012). In contrast, a Hidden Markov Process has states that are not directly visible. HMM has proved to be a successful technique for statistical pattern analysis in a variety of fields including biological sequence analysis, malware detection, speech recognition, just to name a few (Annachhatre et al., 2014). The major limitation of HMM stems from the Markov property itself, in the sense that HMM is memoryless and does not give the possibility to model dependencies between distant events (Schuster-Bockler and Bateman, 2007).

Recently a new term Artificial Intelligence in Education (AIED), has been coined. AIED is expected to impact on the educational landscape in bringing customised learning materials, technology enhanced/enabled assessment, innovative means of teaching and enhanced communication between the learner and the teacher (Chassignol et al., 2018).

2.11.2 Machine Learning

Machine Learning is a subfield of Artificial Intelligence which consists of algorithms designed to emulate human intelligence and which are able to determine patterns/trends (El Naqa and Murphy, 2015). In this era characterised by big data analytics, Machine Learning is expected to play a pivotal role by making reliable predictions. Machine Learning techniques have been successfully applied to fields such as computer vision, pattern recognition, finance and computational biology, just to name a few. One of the distinctive properties of these algorithms, is their ability to learn from the environment and from input data, even with or without the intervention of a teacher. Hence, in simple terms, Machine Learning can be pictured as a set of algorithms that parse data, learn from the set of data and then eventually apply their understanding to take decisions.

According to the nature of the data labelling, Machine Learning can be classified into three categories, namely, supervised, unsupervised and semi-supervised learning. There is still another category of Machine Learning, termed Reinforcement Learning. This one, though, substantially different from structured and unstructured learning is worth some discussion. This is shown in table 2.4 below.

Table 2. 4: Categories of Machine Learning

Classification	**Description**
Supervised Learning	Supervised learning is used to estimate an unknown (input, output) mapping from known (input, output) samples, where the output is labelled (El Naqa and Murphy, 2015). Hence, in a supervised learning model, the algorithm learns on a labelled dataset providing an answer key that the algorithm can use to evaluate its accuracy on training data. A very simple example that can be used to explain this is to train a system to recognise an apple from an orange. Human beings, understand that oranges and apples have certain distinctive characteristics and are able to differentiate them. From a system point of view, rather than 'hard-coding' different representations of apples and oranges, the system is programmed to distinguish them through repeated experience with actual apples and oranges. Each training example of input data (shape, colour, odour, and other features) is paired with its known classification label (apple or orange). This example correctly depicts a supervised learning process in which the system should be able to positively identify a type of orange or apple it has never seen before. A system that behaves positively with examples and data it has processed before but that performs very badly with data it has not seen is known as over-fitting.

Unsupervised Learning	Another category of machine learning happens through unsupervised learning. The algorithm finds its own way through the training input data. This type of data is unlabelled and the algorithm tries to make some sense on its own by extracting patterns and features. For example, questions such as 'are there any correlations between the features' might be asked.
Semi-supervised Learning	Another category of machine learning lies in between structured and unstructured and is termed semi-structured. This category has seen some progress in the recent years and operates through the fact that part of the data is labelled and other parts are unlabelled. The labelled part can be used to aid the learning of the unlabelled part (El Naqa and Murphy, 2015).
Reinforcement Learning	This is another category of Machine Learning Algorithms that controls learning by using a feedback system through the use of an agent which takes a sequence of actions so as to maximise a cumulative reward (El Naqa and Murphy, 2015). (Sutton and Barto, 2016; Badgwell et al.,2018) describe Reinforcement Learning as a system where a Reinforcement Learning Agent identifies the best way of learning a task through repeated interactions with its environment. An analogy that can be used to explain Reinforcement Learning is that of a child's brain that can be taught what is right and what is wrong through the use of punishments and rewards. The child's brain subject to appropriate education will thereafter develop into an adult's brain.

The basic machine learning framework consists of two sets of data. The first is the Training Data, that is used to train the classifier and the Test Data that is used to evaluate the classifier. The success of a particular algorithm also depends on two criteria. The first one is its ability to tackle repetitive tasks and the second one, lies in its ability to uncover subtle and complicated patterns, difficulty seen by the human eye. Both of these are issues that definitely need to be addressed in the field of education. Complex computing systems using machine learning algorithms can serve people with all types of abilities and engage to a certain degree in human-like processes and complex processing tasks that can be employed in teaching and learning. This opens to a new era for institutions of higher education (Popenici and Kerr, 2017). This type of human-machine interface presents the immediate potential to change the way we learn, memorize, access, and create information.

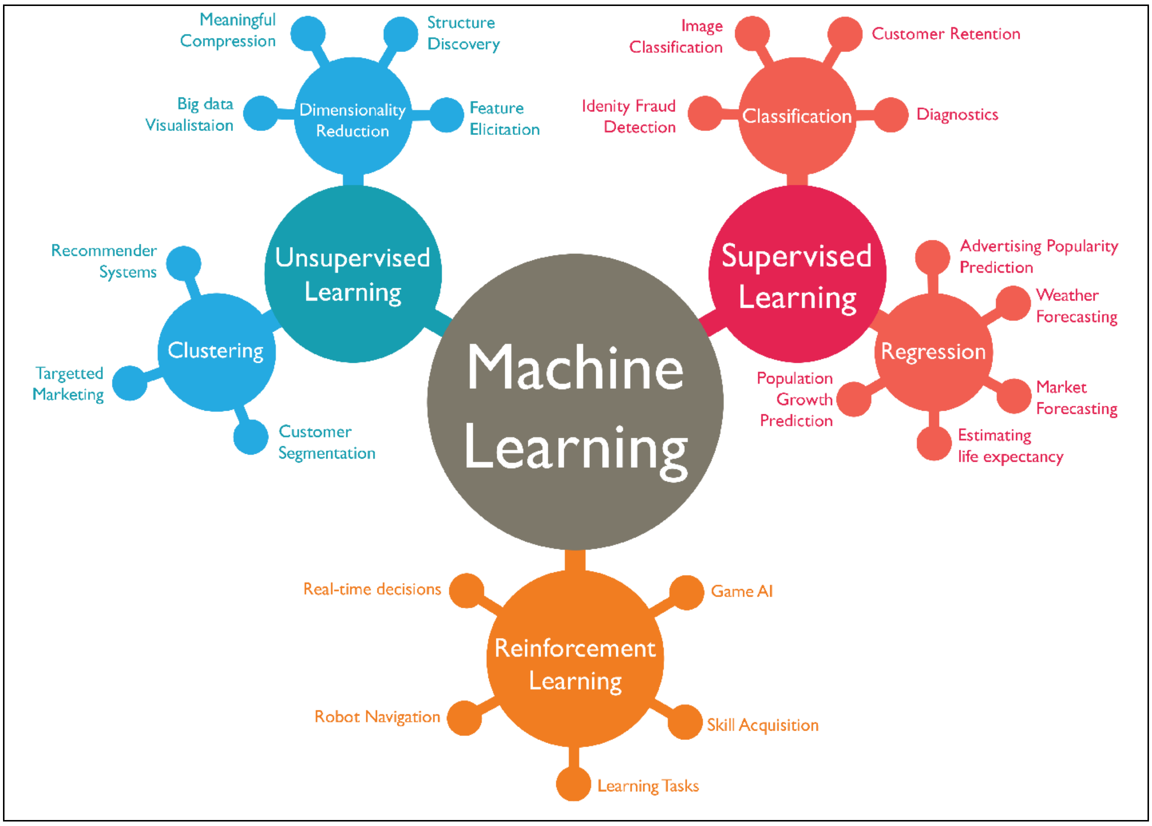


Figure 2. 13: Machine Learning (Source: Adapted from Wahid, 2017)

2.11.3 Neural Networks

Neural Networks are computing systems inspired by biological neural networks that help machines reason like a human would (Acharya et al., 2003). Neural networks have been commonly used for prediction, pattern recognition and pattern classification (Chattopadhyay and Bandyopadhyay, 2007). An Artificial Neural Network (ANN) comprises of processing elements namely: nodes, neurons and the connections and can be imagined as a circuit of neurons. The nodes are related layer-wise. The learning process of the Artificial Neural Network can be supervised or unsupervised. In prediction problems, supervised learning is preferred where a desired output is assigned to a network beforehand. The most popular learning algorithm used for prediction purposes is the Backpropagation Algorithm, which is a supervised learning algorithm (Chattopadhyay and Bandyopadhyay, 2007). Though Artificial Neural Networks have been around for years, the advent of the Backpropagation Algorithm has given a definite boost to the use of ANN. The Backpropagation (BP) algorithm uses a layered neural network approach. That is, the input layer, the hidden layer and the output layer. The network learns by adjusting the interconnection between the layers. Figure 2.14 and 2.15 illustrates a BP neural network.

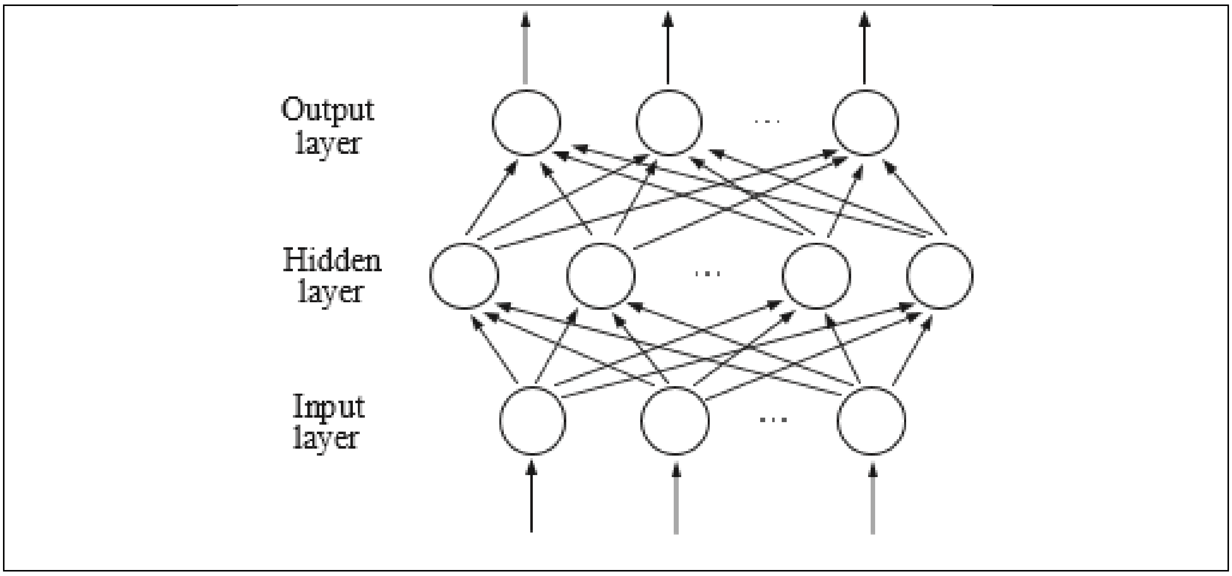


Figure 2. 14: Artificial Neural Network

(Source: Researcher's own construction)

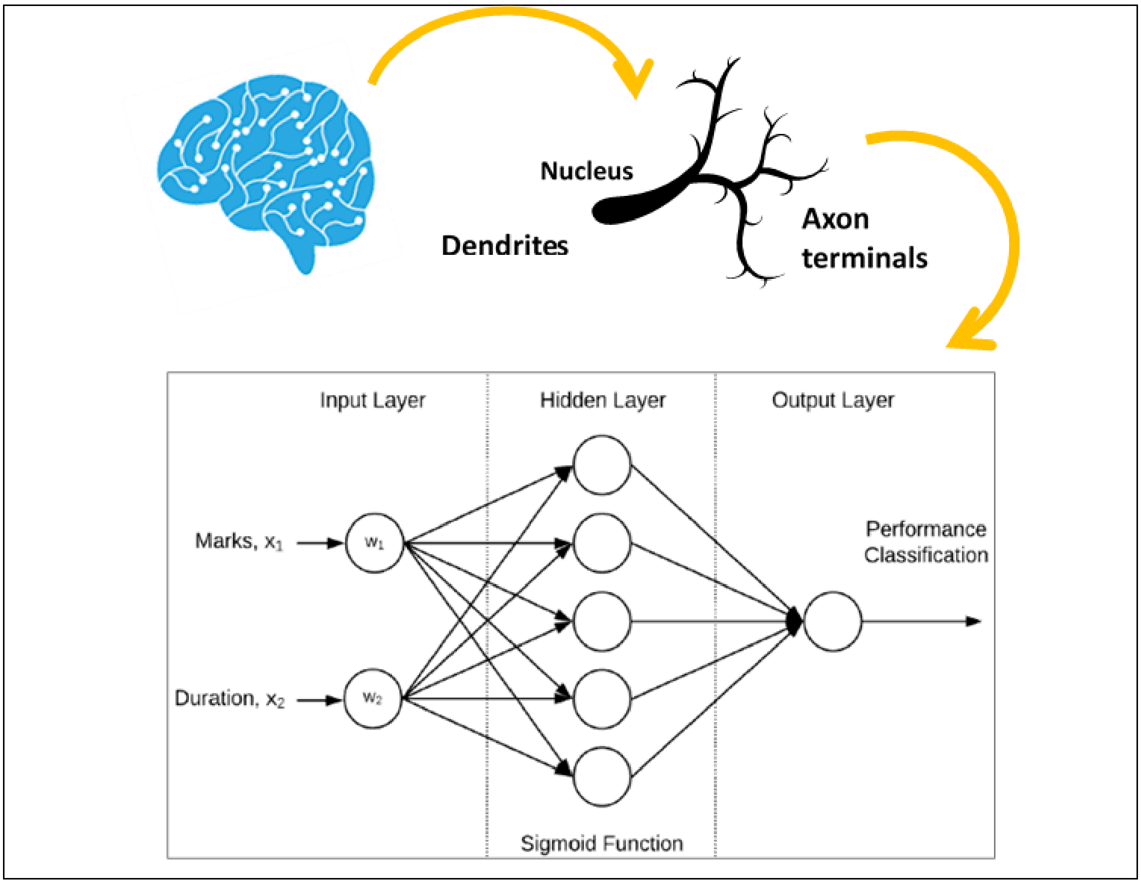


Figure 2. 15: Analogy between Human Brain and ANN

(Source: Researcher's own construction)

At first, the BP algorithm receives an input vector and directly passes it into the hidden layer. Each element of the hidden layer is used to compute an activation value by summing up the weights of each input and the sum of the weighted input will be mapped into an activity level by using a transfer function. Each element of the output layer is then used to compute an activation value by adding up the weighted inputs attributed to the hidden layer. A transfer function is used to calculate the neural output. The actual neural output is then compared to a target value. The BP algorithm refers to the propagation of errors of nodes from the output layer to nodes of the hidden layer. Also, the BP algorithm will be trained in an attempt to look for a behaviour in a training set which needs to be incorporated.

Example of Artificial Neural Network using Backpropagation Algorithm

The BP algorithm operates on a gradient-descent algorithm to minimize the error in the predictions of the Machine Learning technique. The relevance of the BP algorithm arises from the fact that initialising the weights to be used right from the start can prove to be a tedious task.

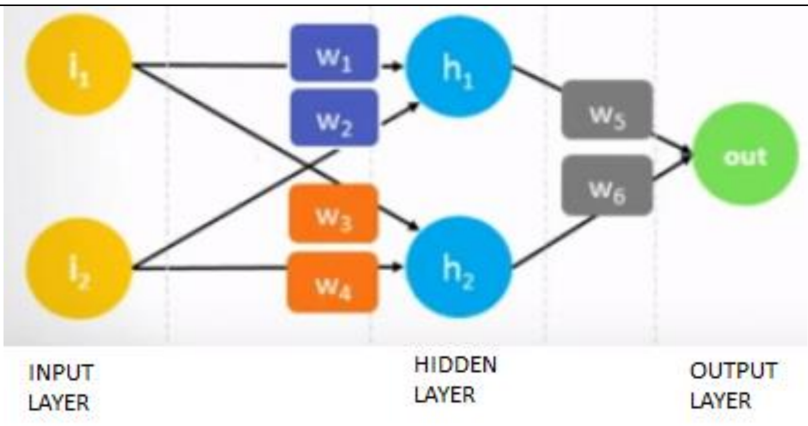


Figure 2. 16: Initialising the weights in the ANN

For example, if the diagram below, weights w1 to w4 have to be initialised with random values. There is a least probability that whatever values have been assigned will lead to the correct output which is needed.

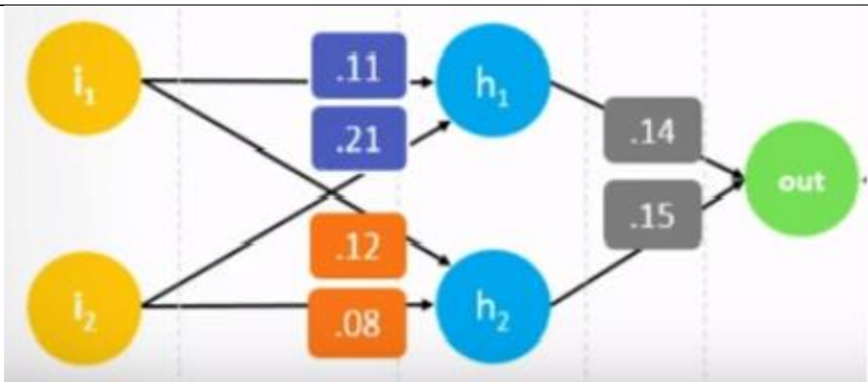


Figure 2. 17: Initialising the weights in the ANN with values

The model is way different from the actual output and the error output which is computed as follows is high.

$$\text{Error} = 0.5\,(\text{prediction} - \text{actual})^2$$

Figure 2. 18: Error

If the Error is 0, this means that the predicted output is equal to the actual value. The value of the Error is always positive because of the square. The parameters are changed such that Error becomes minimum. This is achieved through gradient-descent.

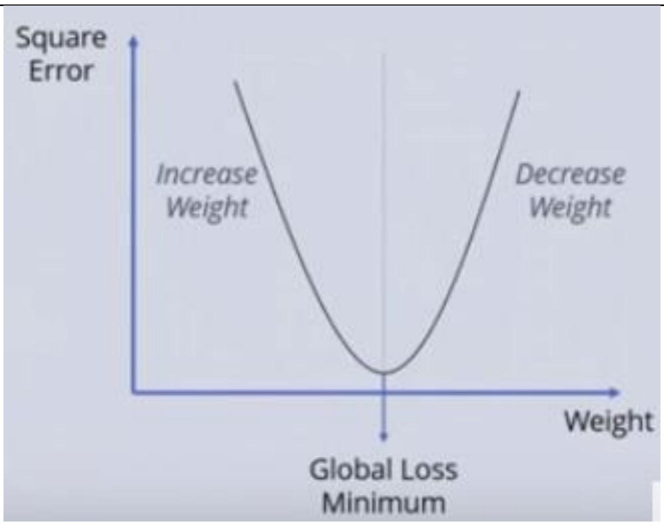


Figure 2. 19: Gradient- Descent Algorithm

The Gradient-Descent method, which is also used to find the minimum of a function, updates the weight by reducing the Error function. The training of the model is shown in the diagram below.

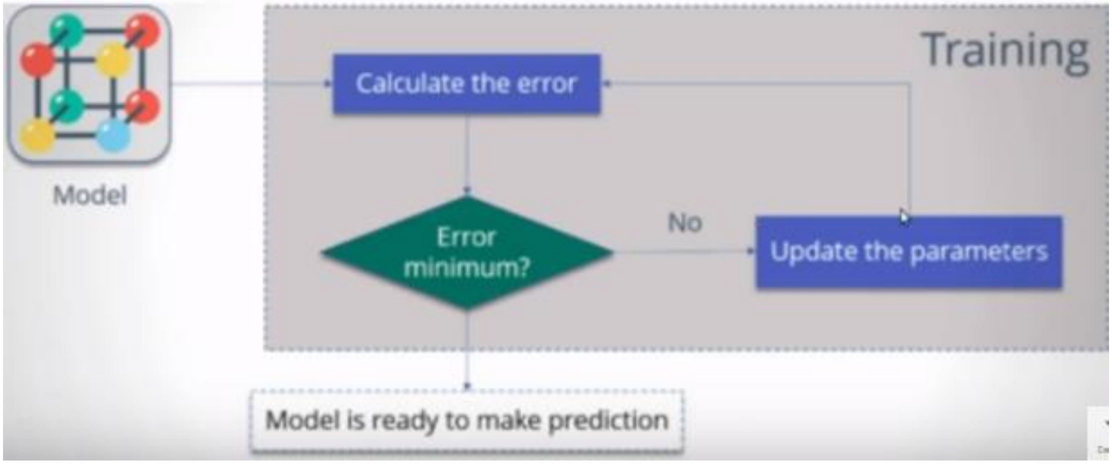


Figure 2. 20: Training the model

The model is initialized with some random values and in the first instance, the error is calculated in the forward pass. If the Error is minimum, the model is ready for prediction, otherwise the parameters are updated and the Error is calculated again. The process is repeated until the minimum error is achieved. This process is known as training the model.

2.11.4 Deep Learning

Deep learning is a subset of machine learning and has had significant contributions in applications, the most well-known being, self-driving cars, image recognition, object recognition and storm detection. The development of its computational model was inspired by the human brain. It is often referred as deep neural networks (DNN) but usually called convolutional neural networks (CNN), since it is a representation of very large neural networks. The deep neural network consists of more than one hidden layer and complex algorithms which do not need to be explicitly coded (Nicholson, 2017). Deep learning also allows for computational models that are composed of multiple layers of processing to learn representations of data with multiple levels of abstraction (LeCun et al., 2015). When the labelled dataset is input in the DNN, it firstly identifies the features. The advanced and beneficial part of the DNN is that it trains the dataset by itself for the recognition of patterns and more data is fed into the DNN, more computation will occur resulting into better algorithms, better recognition of features and more accurate output (Brownlee, 2016).

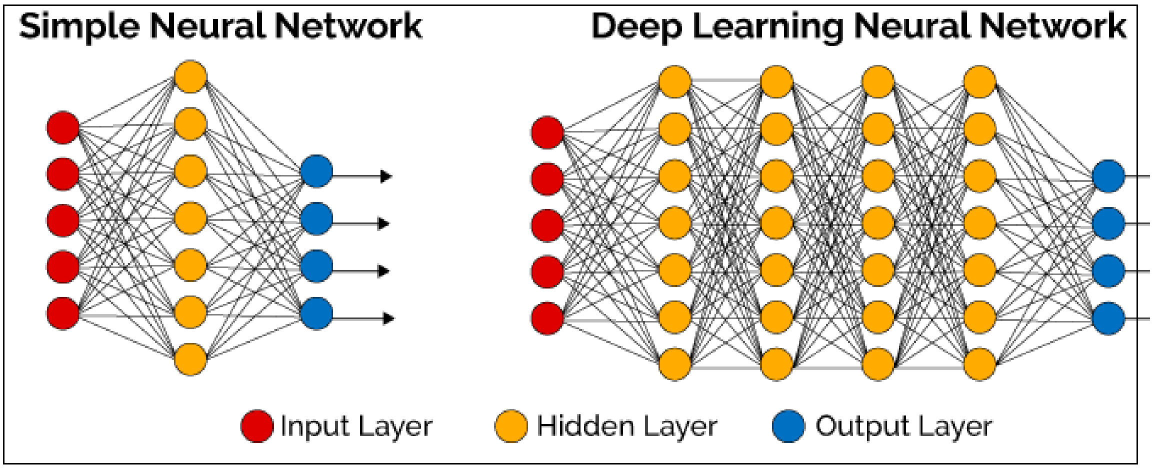


Figure 2. 21: Simple Neural Network v/s Deep Learning Neural Network

(Source: Edwards, 2018)

Deep Learning is powered by large data sets. A common analogy to depict this situation is that of a rocket engine powered by fuel. The rocket engine is analogous to the Deep Learning Models whereas the fuel is analogous to the huge amounts of data that needs to be fed into the algorithms. Hence this is the reason why Deep Learning needs high-end machines as compared to the use of traditional machines with the use of Machine

Learning. The definite advantage of Deep Learning becomes apparent when it comes to the tackling of complex issues such as natural language processing, image classification and speech recognition.

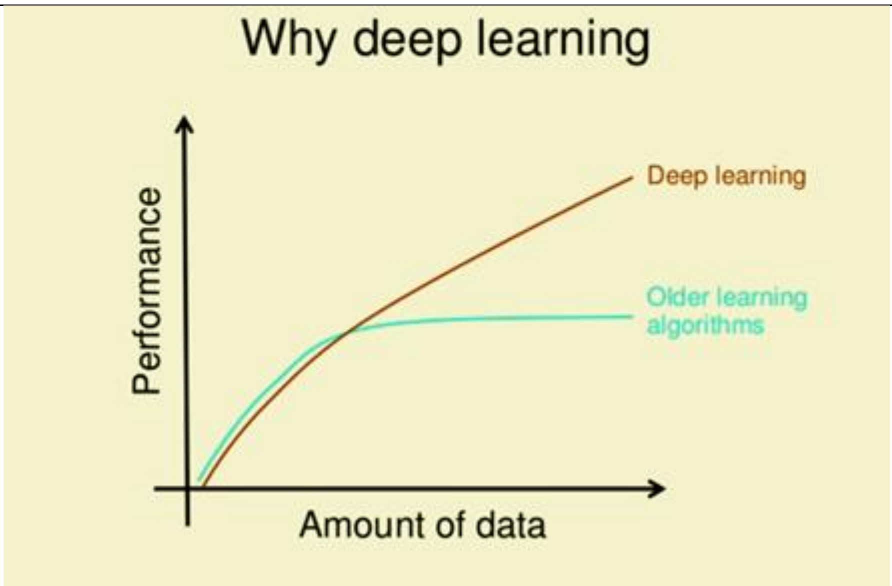


Figure 2. 22: Deep Learning v/s Older Learning Algorithms

(Source: Mahapatra, 2018)

2.11.5 Agent Based Technology

A software agent is an autonomous and independent high-level software abstraction, capable of performing a process without the user's intervention (Alexandru et al, 2015; AgentBuilder, 2017). For example, the agent collects and analyses information, draws conclusions, makes recommendations, and performs transactions in view of achieving its design objectives (Bellifemine et al, 2007). Software agents can be used to implement an Agent-Based Learning Environment that will eventually provide a more customised and unified learning environment. This can in turn provide the learners with a more transparent process to make them focus on knowledge to be conveyed and not on how to use the tutoring tools (Lavendelis and Grundspenkis, 2010). Pedagogical agents are autonomous software entities that support human learning by interacting with students/learners and authors/teachers and by collaborating with other similar agents, in the context of interactive learning environments. Pedagogical agents provide the necessary infrastructure for knowledge and information flow between the clients and the servers. They play an important role as they help in locating, browsing, selecting, arranging and integrating educational materials across different educational servers (Zeng et al., 2009). Interaction between software agents is a key concept in agent-based systems. Software agents repeatedly interact to share information in view of performing their respective tasks. An agent communication language, which can be in the form of procedural or declarative schemes is commonly used (Genesereth, 1997; Chen, 2008). In the procedural approach, communication between software agents happens on executable contents and can be accomplished through the use of programming languages. On the other hand, for the declarative approach, declarative statements through the use of declarative agent languages such as Knowledge Query and Manipulation Languages (KQML) can be used. A SMART Learning Environment using Agent-Based Technology, where the user's preferences and aptitudes can be captured in a pervasive and non-obstructive way, is indeed possible and has been described in the research of Chen (2008). (Nadrljanski et al, 2018) also describes an e-learning environment which is able to achieve personalisation through the use of a Multi-Agent System (MAS). Multi-Agent Systems are characterised by a set of intelligent software agents that interact through well-defined protocols to achieved their intended goals. This interaction can either be perceived as cooperative or competitive and the goals to be achieved can be classified as individual or group (Alexandru, 2015).

2.11.6 Semantic Web

The contribution that the Web has brought to humanity is undeniable. The evolution from Web 1.0 to Web 2.0 has been well-documented (Bogoslov, 2018; Bouhaï and Saleh, 2018; Bloch, 2018). The semantic web, also known as Web 3.0, is a new technology which is seen as the future of the Web. Semantic Web technologies and applications are becoming increasingly popular and adopted in different fields, including education. Research (Jensen, 2017; Beldjoudi et al., 2018) has already shown some of the features and functionalities expected to be embedded in the next generation of learning support systems. Such features include: more adaptive and personalized learning environments, a better use of pedagogies to enhance instruction/learning, effective information sharing, storage and retrieval, new forms of collaboration with peers, and many other characteristics that enable the realization of AAAL; Anytime, Anywhere, Anybody Learning.

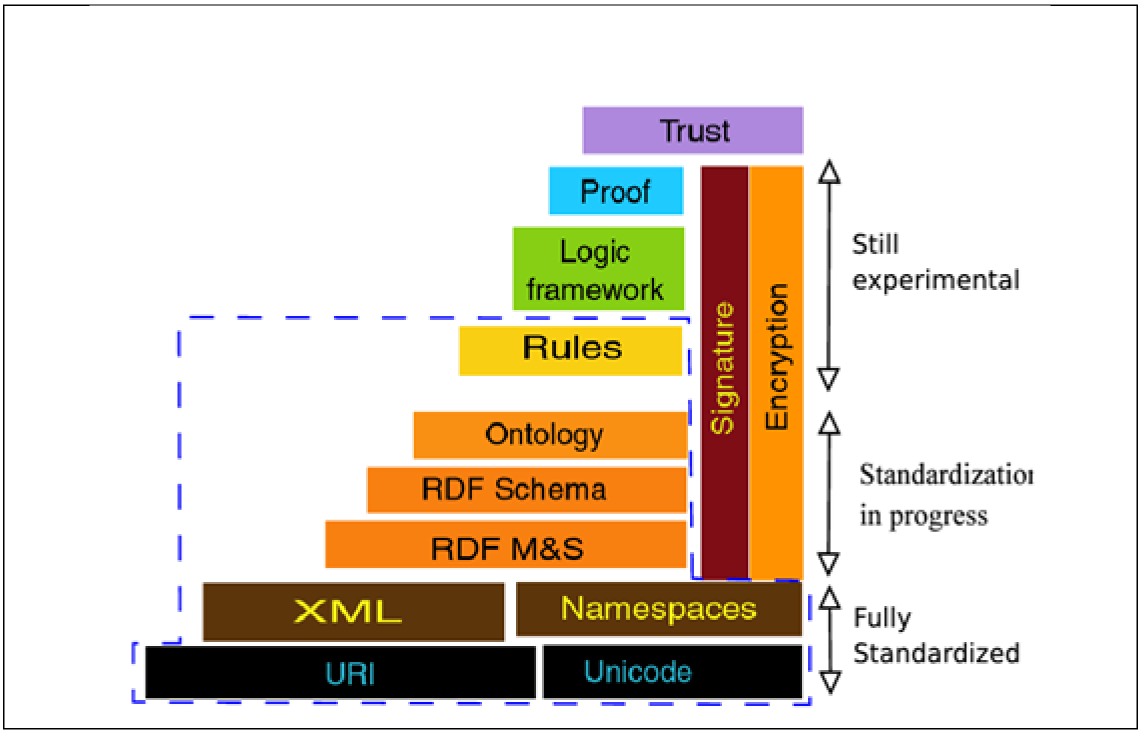


Figure 2. 23: Semantic Web

(Source: www.w3.org, 2019)

2.11.7 Cloud Technologies

Cloud Computing is the use of computing resources, both hardware and software that can be delivered as a service over a network (Goh, 2010). Cloud computing assists mobile devices to overcome constraints in terms of data storage, bandwidth, heterogeneity, scalability, availability, reliability, and privacy. From a cloud learning service perspective, SMART Education provides free access to rich contents developed by public and private institutions and individuals in education, expands the joint use of domestic and international learning resources, and promotes collaborative learning through content delivery platforms (Jang, 2014).

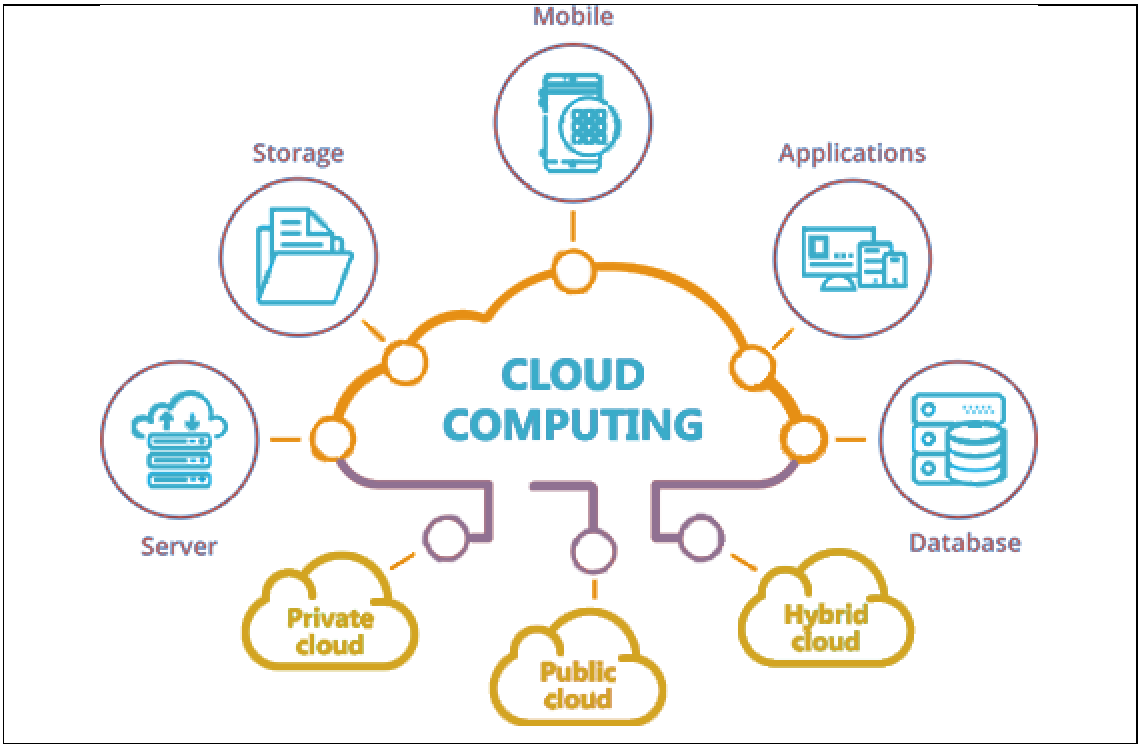


Figure 2. 24: Cloud Computing

(Source: https://www.networksunlimited.com/, 2019)

2.11.8 Educational Data Mining and Learning Analytics

Today's learning process and practices are highly complex and present a number of challenges. One of them being that it is much harder for teachers to control, observe and adjust the learning process. On the other hand, Online Learning Environments generate large amounts of data related to learning and teaching processes with the possibility of extracting useful information that can be used to improve the learner's performance and experience (Calvet Liñán and Juan Pérez, 2015). The idea is to use this immense pool of data to make some sense out of how learners actually learn and to eventually ensure that their learning experience is enhanced. This is further supported by Data Mining, which is the process of finding trends and patterns in large data sets. Educational Data Mining (EDM) develops and adapts statistical, machine-learning and data-mining methods to study educational data generated by students and instructors. Their application may help to analyse student learning processes considering their interaction with the environment (Baker et al., 2012). Learning analytics (LA) can integrate the analysis of user interaction logs, learning resources, teaching goals, and the activities of students from different sources, in order to improve the creation of predictive models, recommendations, and reflections (Santos et al. 2012). The main goal of EDM and LA is to extract information from educational data to support education-related decision making. Information may be oriented towards several stakeholders (Daradoumis et al., 2010). Learning Environments can provide huge amount of data that can be analysed to build learner profiles, personalise their learning experience and monitor their progress. Greller and Drachsler (2012) proposed a six-dimension framework that uses a General Morphological Analysis for Learning Analytics. This is represented below where the six dimensions are Technologies, Educational Data, Objectives, Stakeholders, Competences and Constraints.

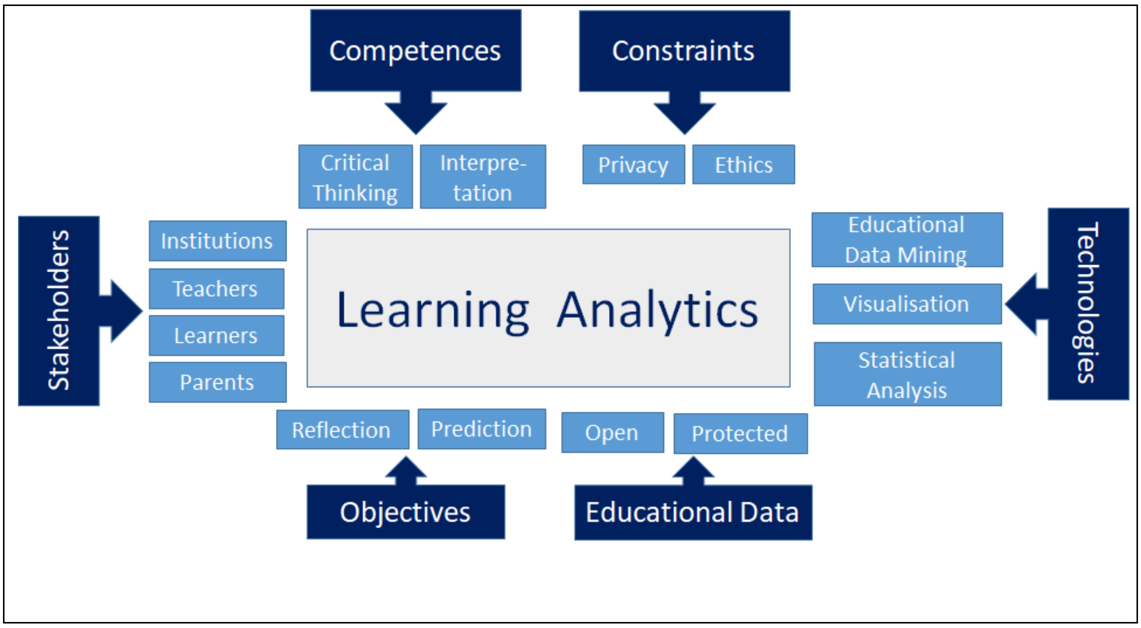


Figure 2. 25: Critical Dimensions of Learning Analytics

(Source: Adapted from Greller and Drachsler (2012))

2.11.9 Sensor Technologies and IoT

With the widespread use and reduction in price of Sensor Technologies and IoT Devices, using the latter to develop SMART Learning Environments remains a plausible alternative. This has been supported by a number of researchers including Lei et al. (2013) and Freigang et al, (2018). Sensors basically measure some properties in their immediate environment such as noise, pressure, light, acceleration and respond with feedback. There are numerous definitions of Internet of Things in educational literature. For Vermesan and Friess (2015), The Internet of Things connects the physical world of objects with the virtual world of data. Applied to educational purposes, this means that the Internet of

Things connects the physical world of (learning) objects with the virtual world of personal learning environments and its learning histories (Freigang et al, 2018). Lei et al. (2013) described a SMART Learning Environment at a university that is enabled by "smart applications". In the research, the sensors monitored conditions that are conducive for learning such as lighting, air quality and heating. Results show that energy efficiencies have been greatly enhanced and demonstrate that IoT Devices can be successfully integrated into learning spaces so as to create a cyber-physical environment which would motivate the learning process. The notion of context-awareness which can be brought by these IoT or 'SMART Devices' can be highly beneficial for the setting up of a SMART Learning Environment. Of course, IoT is only one of the numerous technological possibilities that can be envisaged for the creation of a SMART Learning Environment.

2.12 Lifelong Learning and SMART Learning Environments

The 21st Century Knowledge Economy is a complex and an ever-changing one. Professionals find themselves in need of continually updating their skills so as to meet the job market needs. A culture that fosters emergent knowledge to be captured and acted upon by professionals at their respective workplace is a must. It is without doubt that the field of Computing is a highly dynamic one and ICT Professionals who do not continually update their skills and knowledge, will soon find themselves with outdated technical competence. Professionals in the ICT industry need to follow a hectic schedule and pace; and very often the training and up-skilling programmes need to be 'just-in-time'. Organising training sessions by employers also adds up enormously to the budget, not to mention the burden of organising and managing such training sessions. Online training, therefore, appears to be the solution for lifelong learners. With easy access to the Internet, online training is becoming very popular in providing cost-effective learning materials that can be accessed anytime and anywhere (Kim et al. 2014; McCutcheon et al. 2015; Seaton et al. 2014; Gaebel 2017). Learning through MOOCs has gained much popularity in the recent years as described in Section 2.2 but the drop-out rate is high and only 10-20% of learners complete the course they are enrolled in (Hew and Cheung, 2014). However, it is also true that many learners sign up to follow the course and to have access to the learning materials but in the end do not take the exams.

Providing engaging online and life-long learning for working professionals can be even more challenging due to lack of time, distractions at their workplace and daily commitment (Aamodt 2016; Knowles et al. 2015; Button et al. 2014; Choy et al. 2013; Robson et al. 2012; Hager 2004). With the increased availability and access to online learning resources both casual and structured, and with the rapidly changing nature of the work environment, it is important that individuals are able to manage their learning, which is in this context, very often self-directed learning. But a pressing question that needs to be answered is whether the contemporary methods of training and up-skilling available at the workplace are effective and efficient. Newman and Farren (2018) state that the traditional training formats are very often not effective and Ebner et al (2011) states that lifelong learning will change as smart technologies increasingly support the acquisition of skills in the workplace. **Engagement** is also a determining factor in ensuring the success of the learning process since very often, the materials are readily available but the continuous learners feel that they do not have this feeling of control and autonomy. It can therefore be argued that MOOCs have not been able to give this aspect of engagement necessary for self-directed learners to succeed in their learning process. SMART Learning Environments can fill this gap by ensuring that the learners learn at their own pace, bearing in mind their individualities, thereby giving them more autonomy and control. This in turn leads to engagement and motivation, which are essential for the proper learning process.

2.13 Cybersecurity

Cybersecurity, in simple terms, can be defined as the practice of protecting computer and internet based systems, including hardware, software and data against attacks. Critical infrastructures, the economy and society at large is largely dependent on IT systems which are connected to high-speed internet connections. This high dependence makes cyber-attacks more attractive and disastrous (Jang-Jaccard and Nepal, 2014). There is evidence that cyber-attacks have a negative impact on economic growth. The Council of Economic Advisers (2018) argues that malicious cyber activities in the United States have had financial implications between $57 billion and $109 billion in 2016. On the African continent, it has been argued that if the Westgate Mall attack was prevented, it would have prevented a loss of $200 million in tourist revenue and additional costs in infrastructure reconstruction (Kushner, 2013).

According to the Global Cybersecurity Index (GCI) (2018) from the International Communication Union (ITU), Mauritius occupied the 14th position globally and 1st in Africa based on their cybersecurity index. In 2017, Mauritius occupied the 1st place on the African Continent in terms of Cybersecurity as established by GCI and 6th position globally (GCI, 2017). The index is an indication of the level of countries' commitment to cybersecurity based on five criteria: legal, technical and organisational measures in place to tackle cyber related issues, the capacity building mechanisms in place and the level of international cooperation for cybersecurity. The GCI is a global trusted reference that measures the commitment of the country towards Cybersecurity at a global level. At national level, the Government of Mauritius is doubling its efforts in ensuring that the country positions itself as a leader in terms of cybersecurity for the region. In 2018, the Republic of Mauritius established the Mauritian Cybercrime Online Reporting System (MAUCORS) which aims to coordinate and resolve incidents related to Social Media and cybersecurity incidents in Mauritius. Cyber drills for Top Management of organisations in Mauritius were organised in view of sensitising employees of possible scenarios of cybersecurity attacks. The Minister of Technology, Communication and Innovation, on that event, reiterated the need for Mauritius to boost its level of Cybersecurity in view of building a resilient and secure Mauritius. This is in view of consolidating the already existent National Cybersecurity Strategy - 2014-2019 (2014), which up-to-now has served as an umbrella framework to define and guide actions related to Cybersecurity in Mauritius.

Unconstrained by geography, time and distance, hackers are continually doubling their efforts to break into computer systems and to cause harm. Furthermore coupled with this is the fact that computer and network systems are becoming increasingly more accessible and has known an exponential growth. This has led to the fact that the number and sophistication of cyber-attacks is expected to increase in the years to come. Indeed, recent years have seen an increasing number of high-profile cybersecurity scandals and the emergence of new technologies such as IoT, Cloud Computing, Mobile Computing, Blockchain, just to name a few, which are all prone to cyber-attacks. Cybersecurity is a fast-expanding area and also involves a deep understanding of the possible attacks and the ability to devise countermeasures that would enable protecting the confidentiality, integrity and availability of any digital technologies.

The information and cybersecurity posture of any country is intrinsically linked with its security culture (particularly, its cybersecurity culture). The fact that cybersecurity is an emerging discipline suggests that this culture needs to be inculcated and developed; it is not intrinsic to society. While personal security is well understood and practiced in society, there are very little similarities between personal security and cybersecurity. This is why education and awareness as one of the pillars identified by the African Union (AU) Convention on Cyber Security and Personal Data Protection (2014) is of utmost importance. A number of certifications are popular among security professionals and some of the most popular ones are listed below.

- CompTIA Security+
- Certified Ethical Hacker (CEH)
- EC-Council Certified Security Analyst (ECSA)
- Licensed Penetration Tester (LPT)
- Certified Information Systems Security Professional (CISSP)
- Certified Cloud Security Professional (CCSP)
- Certified Information Security Manager (CISM)

2.14 Pedagogy and Learning Styles

Pedagogy is a major component in Teaching and Learning and also applies to Knowledge Transfer taking place through the use of the SMART Learning Environment. Pedagogy plays a central role in the sense that it ensures that the SMART Learning Environment provided is conducive for learning. In the traditional classroom environment, the teacher was the celebrated expert, dispensing knowledge (McLoughlin and Lee, 2010) but it in a

SMART Learning Environment, the learner is an independent participant who is self-regulated and who embraces the notion of constructivism. Indeed, the theory of constructivism stresses on the fact that the learner aims at actively constructing knowledge instead of passively receiving and storing knowledge from a teacher (Ben-Ari, 2001).

There are many different learning style models. A learning style is a set of student's individual characteristics that are reflected in his learning behaviour; how the learner learns, how the learner should be taught, and how the learner interacts with the learning environment (Chang et al., 2009; Keefe, 1987; Tseng et al., 2008). One common Learning Style Model is the VAK (Visual, Auditory and Kinesthetic) Model. This Model stipulates that visual learners would prefer to have their learning materials in the form of charts, graphs, diagrams and other symbolic representations instead of pure text and word. Auditory learners on the other hand would prefer to have their learning materials in the form of audio lessons, Kinesthetic Learners would have a better inclination towards learning by doing, through the use of practical sessions and simulations (Ocepek et al., 2013). The Learning Styles Models have been subject to much criticism and some researchers totally disagree with the concept and even argue that their existence is a pure 'neuromyth', even though their use remains widespread (Newton, 2015). It is true that Learning Styles is one of the Intrinsic Factors that can be used to differentiate between learners and the way they learn. However, using Learning Styles as one of the parameters to provide different learning materials to learners and thereby providing personalisation is beyond the scope of this research. The researcher also has not been venturing in this direction since a number of contradictory perceptions of Learning styles are present amongst researchers. However, through the VAK model, it has been understood that the learning materials to be used in the SMART Learning Environment can be presented in a number of media/multimedia formats through the use of text, internet-based access to Online Resources, graphic, charts, diagrams, audio session, video session, simulation, online interactive multimedia, practical exercises, just to name a few. Another way of categorising learning styles can be through the adoption of Felder-Silverman's learning style categories. According to this approach, learning styles can be classified as follows (Chen and Zhang, 2008; El-Bishouty et al., 2018)

i. **Sensing v/s Intuitive**: This describes the way the learner prefers to perceive or to take in information. The sensing learner prefers concrete thinking supported by procedures and facts. The intuitive learner on the other hand, is innovative, favours theories and encourages conceptual thinking

ii. **Visual v/s Verbal**: This determines how the information is presented. The visual learner prefers information given in visual representations such as pictures, diagrams and flowcharts. The verbal learner prefers spoken and written explanations.

iii. **Active v/s Reflective**: This determines how the learner would prefer to process the information. The active learner prefers to try things out while discussing and experimenting in groups. The reflective learner, on the other hand, prefers to think things through, through introspection or/and through discussions with a familiar partner.

iv. **Sequential v/s Global**: This describes how the learner would prefer to organise and progress towards understanding the information. The sequential learner progresses linearly, step-by-step and in small incremental steps. The global learner prefers to think in a holistic way, learn in large leaps and can be termed as system thinkers.

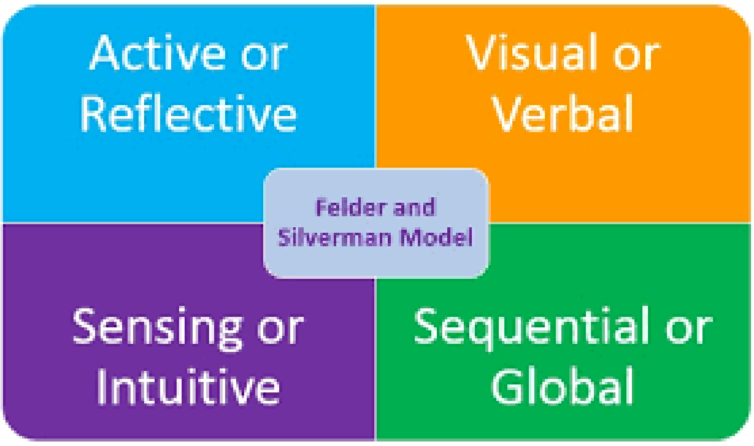


Figure 2. 24: Felder-Silverman's learning style categories (Chen and Zhang, 2008; El-Bishouty et al., 2018)

2.15 Chapter Summary

A survey of the literature as related to the main research questions and objectives is presented. This chapter starts with an evolution of technology-enhanced learning and latter highlights the major shortcomings of contemporary methods such as MOOCs and E-learning. The way forward in terms of Technology Enhanced Learning, presented here as SMART Learning Environments is put forward as well as the techniques and challenges for developing such environments. Theoretical Frameworks, Conceptual Models and the Research Design are presented in the next chapter.

CHAPTER THREE: THEORETICAL FRAMEWORKS, CONCEPTUAL MODEL AND RESEARCH DESIGN

"Patience and perseverance have a magical effect before which difficulties disappear and obstacles vanish." —John Quincy Adams

Section A: Theoretical Framing and Conceptual Model guiding the Thesis

3.1 Introduction

There are many definitions of research but one word that appears often is 'theory'. De Vos et al. (2005) argues that research is a systematic, controlled and critical investigation of natural / social phenomena that is guided by theory and hypotheses about the presumed relations among such phenomena. This statement is further sustained by Imenda (2014) which states that without theory, research would lack direction. A theory can be thought of as the conceptual basis for understanding, analysing and designing ways to investigate relationships within social systems (USCLibraries, 2019). Fox and Bayat (2007) define theory as a set of interrelated propositions, concepts and definitions that present a systematic point of view of specifying relationships between variables with a view to predicting and explaining phenomena. Theories are formulated to explain, predict, and understand phenomena; and, in many cases, to challenge and extend existing knowledge within the limits of critical bounding assumptions.

The use of the theories in this research study can be viewed from two perspectives:

i. That which underpins research design to inform research methods and tools (using the theory as a paradigm).

ii. That which informs our understanding of the phenomenon under investigation as explained in the results (using the theory as a lens).

Imenda (2014) also adds that in every research, the researcher is expected to present an appropriate theoretical framework, thereby stressing the importance of the use of a proper theoretical framework to guide the research. In simple terms, a theoretical framework introduces and describes the theory that explains the need to have the problem under investigation. The research problem is presented in light of a summary of the existent literature. In other words, the concepts required to understand the various items under study come from different theoretical frameworks from the existing body of knowledge. A logical structure of connected concepts is essential to fully investigate the various aspects of this research. All frameworks are based on the identification of key concepts and the relationship among these concepts. Theoretical frameworks that have been chosen are Design Science Research Methodology (DSRM), Activity Theory, the Unified Theory of Acceptance and Use of Technology (UTAUT) Model and Bloom's Taxonomy.

At this point, it is important to shed light on the difference between a Theoretical Framework and a Conceptual Framework. Theoretical Frameworks are existing theories in Literature that have been tried and tested, for example Bloom's Taxonomy. A Conceptual Framework is obtained by the researcher joining concepts together in a cohesive way so as to explore a research problem and to further propose a model that better represents concepts in the research as compared to existing theoretical models (Regoniel, 2010). (Imenda, 2014; Liehr and Smith, 1999) argues that the researcher eventually proposes a Conceptual Model, whereby existing views from literature has been 'synthetised' and this further represents an 'integrated' way of looking at the problem.

This chapter begins by providing a theoretical overview of Design Science Research Methodology (DSRM), Activity Theory, the Unified Theory of Acceptance and Use of Technology (UTAUT) Model and Bloom's Taxonomy. Key aspects of these theories and their relevance to this research are thoroughly discussed. An understanding of these different theoretical frameworks and models is important so as to be able to eventually formulate a strong conceptual framework. This Conceptual Framework has been crafted from the existing theoretical models and its academic credibility is further discussed in Chapter 7 (Discussion and Interpretation of Findings).

3.2 Design Science Research Methodology (DSRM)

Science may be viewed as the process of designing theories (Walls et al., 1992). While science is concerned primarily with analysis, design is oriented towards synthesis. A scientist becomes a designer when instruments are designed to test theories, and a designer sometimes becomes a scientist when scientific theories are applied in implementing the designs. The purpose of a theory is prediction or explanation of a phenomenon (Adebesin et al., 2011). Design science have been widely used in engineering and computer science and recently researchers have succeeded in bringing design research into the Information Systems (IS) research community (Peffers et al. 2007). The figure below show the Peffers et al. (2007) Design Science Research Methodology (DSRM) Process Model.

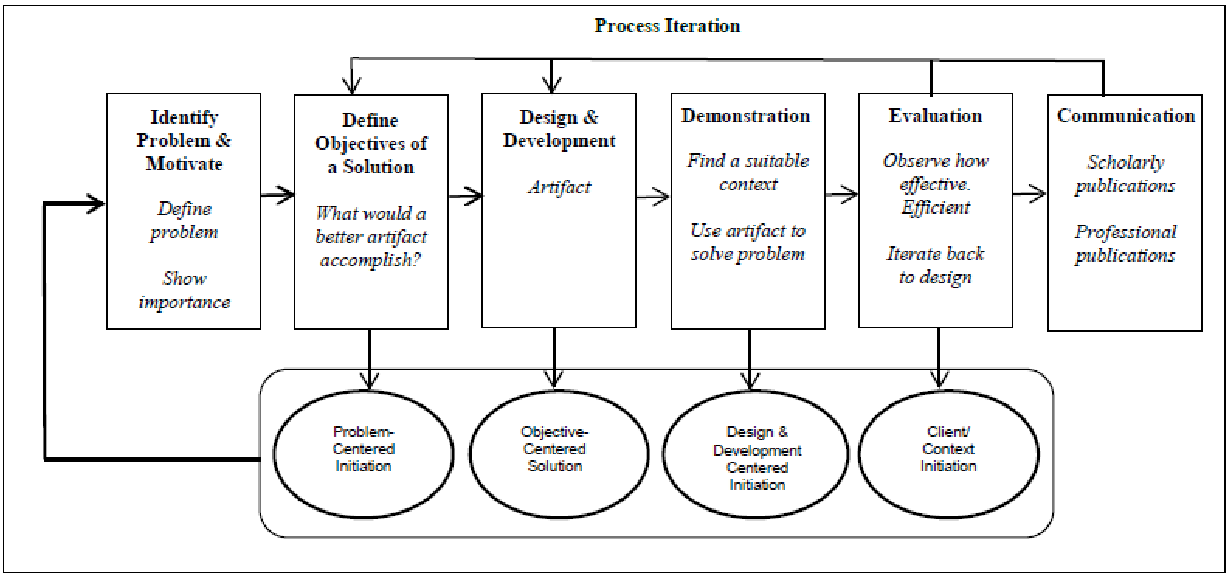


Figure 3. 1: Design Science Research Methodology Process Model

(Source: Extracted from Peffers et al. 2007)

According to the figure above, the DSRM process model is divided into the following stages, namely:

- Identify Problem & Motivate;
- Define Objectives of a Solution;
- Design & Development;

- Demonstration;
- Evaluation and
- Communication.

This theoretical framework includes three elements namely, conceptual principles to define what is meant by design science, practice rules and finally a process for carrying out and presenting the research (Peffers et al. 2007). According to Peffers et al. (2007) this theoretical model will assist the acceptance of design science research within the IS discipline as it uses analytical techniques to create things to serve humans. DSRM enable the IS researcher to make research contributions, to evaluate their designs and finally to make appropriate audiences aware of their results. Such artefacts may include constructs, models, methods, and instantiations (Hevner et al. 2004).

Design science research involves two primary activities to understand and improve the behaviour of aspects of Information Systems: (1) the creation of new knowledge through design of novel or innovative artefacts (things or processes) and (2) the analysis of the artefact's use and/or performance with reflection and abstraction. The artefacts created in the design science research process include, but are not limited to, algorithms, human/computer interfaces, and system design methodologies or languages (Vaishnavi et al., 2017). Hevner et al. (2004) also puts forward seven guidelines for Design Science in Information Systems Research which is summarised in the table below.

Table 3. 1: Design Science Research Guidelines

(Source: Adapted from Hevner et al., 2004)

Guideline	Description
Guideline 1: Design as an Artefact	Design-science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artefact, design foundations, and/or design methodologies.

Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artefact.
Guideline 6: Design as a Search Process	The search for an effective artefact requires utilizing available means to reach desired ends while satisfying laws in the problem environment
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

It can be argued that Design Science Research Methodology is both a theoretical framework and a research design approach. Besides providing a natural framework for performing research in Information Systems, DSRM has long been privileged for the development of software artefacts (Sawyerr, 2016).

3.2.1 Relevance of DSRM in this research

The advantage of using DSRM in this research study is that it enables IS researchers to present high quality design science research that is accepted as valuable, rigorous, and publishable in IS research outlets (Peffers et al. 2007). Indeed DSRM ensures that the development of the SMART Learning Environment is done through a rigorous process, where feedback and communication form an integral part, thereby ensuring an application of high quality and standard. The development of the SMART Learning Environment, in the form of an artefact, is critical to be able to assess its effectiveness in solving a 'business problem', in the researcher's case, a national problem, elaborated in Chapter 1. The relevance of using DSRM is further confirmed by Hevner et al. (2004), who pointed out in Design-Science Research Seven Guidelines (Table 3.1 above), that the development of an artefact that addresses a problem is one of the most important considerations of Design Science.

3.3 Activity Theory

Activity Theory was proposed by the Russian psychologist, Vygotsky (1978) as a derivative of cultural-history theory. He argues that human beings deeply understand the things around them and acquire knowledge through their meaningful actions, such as collaborative dialogue, social activities and other types of interaction. Leont'ev (1978,

1981) further expanded this theory into a conceptual framework, while Engeström (1999) extended the ideas of Leont'ev and Vygotsky to explain how the individual or subgroup adjusts the original old frame in response to the challenges of the whole situation changing (Chung et al., 2019). Activity Theory is not a 'theory' in the strict interpretation of the term but consists of a set of basic principles which constitute a general conceptual system which can be used as a foundation for more specific theories. These basic principles of Activity Theory include object-orientedness, the dual concepts of internalization/externalization, tool mediation, hierarchical structure of activity, and continuous development (Bannon, 1995). Activity theory is a general framework for studying different forms of human activity as development processes (Kuutti, 1996). The framework of Activity Theory proposed by Engeström (1999) consists of six elements, namely, **subject, object, tools, community, rules** and **division of labour**. The elements or at times referred to as components, though focusing on distinct areas, are interconnected in a given phenomenon under study (Iyamu and Shaanika, 2019). An explanation of these six elements is summarised in table 3.2 and figure 3.2.

Table 3. 2: Elements of Activity Theory proposed by Engeström (1999)

(Source: Adapted from Chung et al., 2019; Iyamu and Shaanika, 2019)

Element	Description
Subject	A subject can be referred to an individual or group of actors performing an activity. In Uden (2007), Subject is referred to as both technical and non-technical entities, which are engaged in an activity.
Object	Reason why the activities take place. An Object can also be defined as the element or problem to which an action is directed or shaped. It can also be seen as the goals and intention.
Tools	Content or the instrument involved in the activities. Tools shape the way in which people connect with each other and interact. According to Holt and Morris (1993), tools mediate the subject activity towards the object. Tools are used by subjects when performing activities.
Community	Environment in which the activities are carried out. The community is seen to be composed of participants sharing the same object or motive. (Blin and Munro, 2008)
Rules	Strategies, policies and/or regulations that govern actors in their activities over a period of time, and within context. This can also be seen as norms that circumscribe the activity
Division of Labour	This represents allocation of specific tasks in accordance with areas of specialisation of individuals (Holt and Morris, 1993). This can also be seen as actions undertaken by individuals within the group versus tasks that are a group responsibility

The **Outcome** is seen as being the results emanating from an activity being carried out. Each of the six elements or components of Activity Theory, contribute towards the outcome and has an impact which can be positive or negative, depending on the phenomena being studied (Allen et al., 2011). A number of pertinent questions need to be pondered on during the use of Activity Theory in Research. This can be summarised in the figure below.

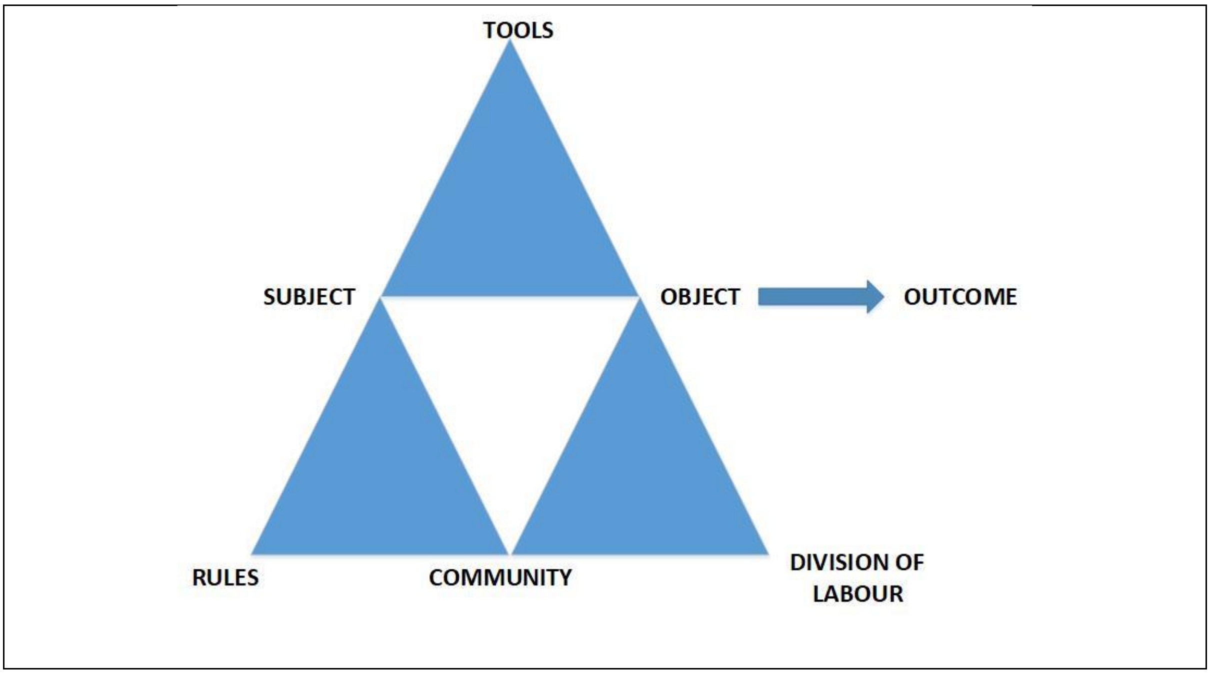


Figure 3. 2: Activity Theory Diagram

(Source: Adapted from Engeström, 1999)

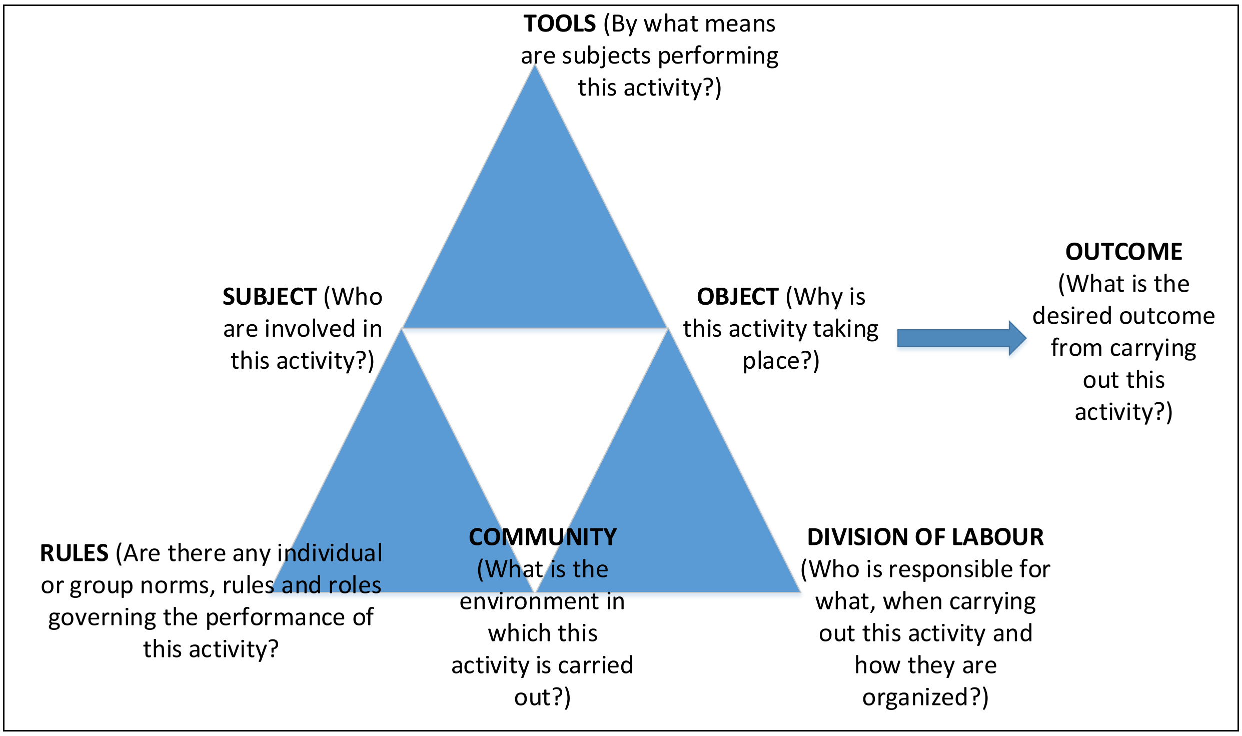


Figure 3. 3: Activity Theory Questions

(Source: Adapted from Engeström, 1999)

3.3.1 Activity Theory in IS and Technology Enhanced Learning Research

Activity Theory is a commonly used theory in Research and Sekgweleo et al. (2017) argues that the theory has been applied more than 3 million times. Information Systems is a field whereby human relationships with technology is commonly studied and therefore the interest of using Activity in Information Systems research comes naturally. Besides Activity Theory is also known for its focus on mediation and tools (Kaptelinin and Nardi, 2018; Iyamu and Shaanika, 2019), the latter being key concepts and components of Information Systems. Activity Theory has been used in a number of studies related to the development of Information Systems in Technology Enhanced Learning, such as computer-supported collaborative learning (Zurita and Nussbaum, 2007), constructivist learning environments (Jonassen and Murphy, 1999), mobile learning (El-Hussein and Cronje, 2010; Fulantelli et al., 2015; Hsu and Ching, 2013), personal learning environments (PLEs) (Buchem et al., 2011), educational serious games (Plass et al., 2015) and educational technology assessment (deFreitas and Oliver, 2006; Scanlon and Issroff, 2005; Tolmie and Boyle, 2000). Given that it is primarily a descriptive tool, AT is geared towards practice. It embodies a qualitative approach that offers a different lens for analysing a learning process and its outcome, focusing on the activities people are engaged in (Zurita and Nussbaum, 2007). In recent years, Activity Theory has been used as a lens for data analysis, predominantly in IS/IT qualitative research (Karanasios et al., 2015).

3.3.2 Relevance of Activity Theory in this research

Though Activity Theory is fundamentally a sociotechnical theory originating from the field of psychology (Yamgata-Lynch, 2010), it's relevance to this Information Systems research is fully justified and validated by a number of researchers (as mentioned in the above section). One of the fundamental pillars of Activity Theory is the development of social activities; which turns out to be a core activity in Information Systems. Activity Theory has successfully been used in a number of research projects related to Information Systems and the development of artefacts to be used in Technology-Enhanced Learning. Activity Theory is usually employed in IS studies to examine the activities of people as they interact with each other in an attempt to achieve a desired outcome (McMichael 1999). Using Activity Theory and the six inherent elements, the following diagram sets out the discussion for the research and phenomenon under investigation.

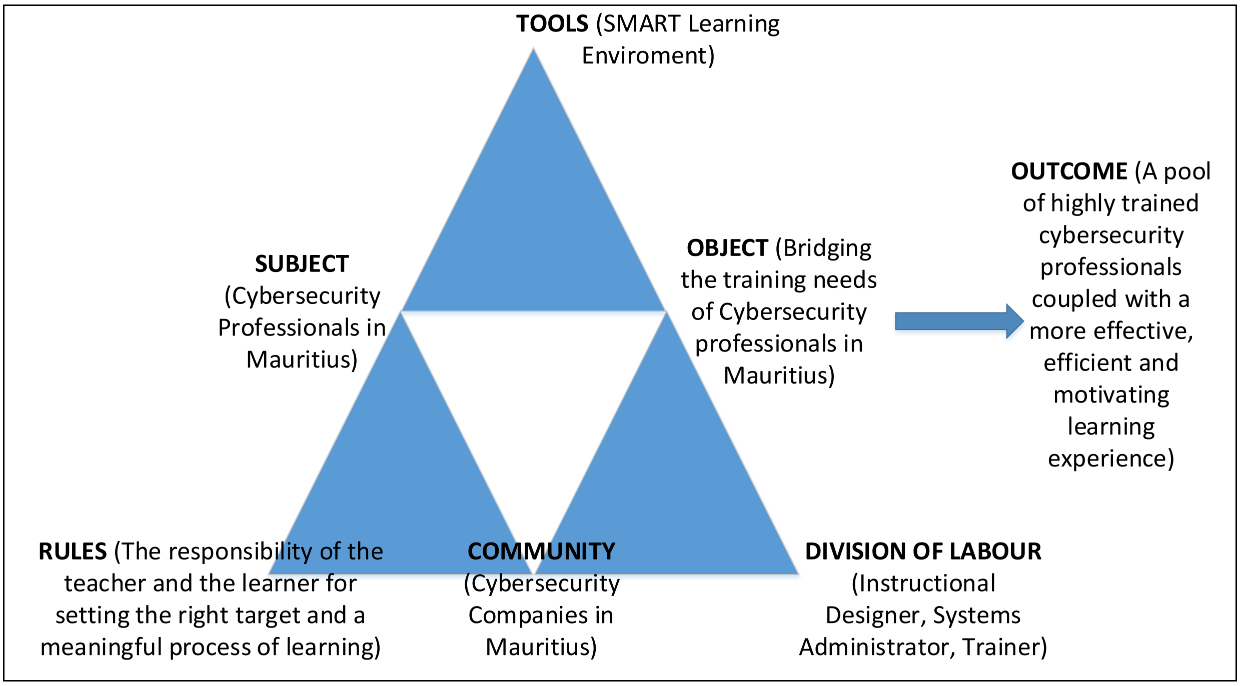


Figure 3. 4: Activity Theory Diagram for this research

(Source: Adapted from Engeström, 1999)

3.4 Bloom's Taxonomy

Bloom's Taxonomy is a classification of the different objectives that educators set for their students (learning objectives). Educators often use Bloom's Taxonomy to create learning outcomes that target not only subject matter but also the depth of learning they want students to achieve, and to then create assessments that accurately report on students' progress towards these outcomes (Anderson & Krathwohl, 2001). Bloom's taxonomy has received considerable recognition internationally within the evaluation community (Lewy and Bathory, 1994) because it was used soon after its introduction at United Nations Educational, Scientific, and Cultural Organization (UNESCO) and Organization for Economic Cooperation and Development (OECD) seminars.

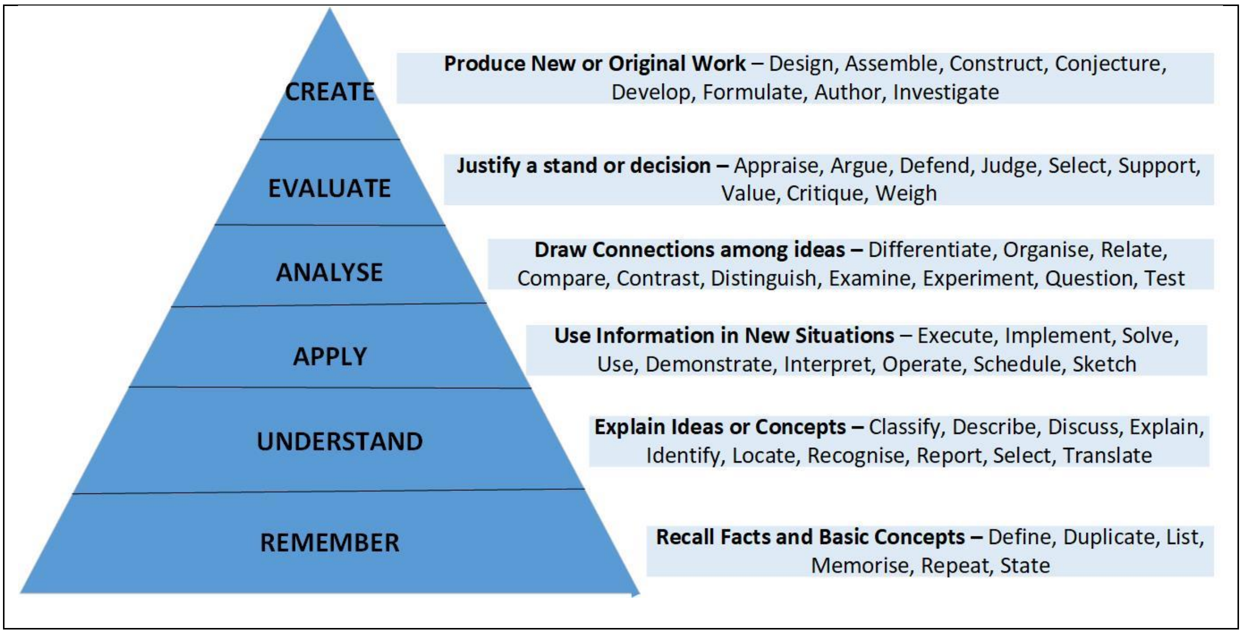


Figure 3. 5: Bloom's Taxonomy

(Source: Adapted from Vanderbilt University Center for Teaching, 2017)

3.4.1 Relevance of Bloom's Taxonomy in this research

Bloom's Taxonomy is relevant in this research since it guides the trainer to set questions that will help learners reach a higher level of thinking and eventually a higher cognitive level. Information Specialists use Bloom's taxonomy to write learning objectives that describe the abilities and skills that they would expect learners to master and demonstrate (Adams, 2015). Since this research aims at the up-skilling of Cybersecurity professionals in Mauritius where they would be learning mostly on their own, Bloom's Taxonomy is appropriate. Indeed, the use of the SMART Learning Environment by the target audience would imply a great deal of student-centred learning. The relevance of Bloom's Taxonomy in student-centred learning is advocated by a number of researchers including (Athanassiou and McNett, 2003), who argue that the use of Bloom's Taxonomy has enabled the learners to become more student-centred and has allowed them to gain increased awareness and control of their own cognitive development. The benefits of Bloom's Taxonomy for this research, are two-fold; one from the instructional design perspective and one from the learner's cognitive development perspective.

3.5 Technology Acceptance Model

The Technology Acceptance Model (TAM) is one of the most widely implemented models in Information Systems research, used to depict the acceptance and usage of technology. This term was first coined in the 1970's following the widespread adoption of technology in organisations, yielding in many cases of failure of system adoption in organisations. Davis (1985) argues that the user's motivation can be explained by three factors, namely: *Perceived ease of use, Perceived Usefulness and Attitude towards using* the system. He hypothesized that the attitude of a user towards a system is a major determinant of whether the user will actually use or reject the system. The attitude of the user, in turn, is considered to be influenced by the two beliefs of 'Perceived Usefulness' and 'Perceived ease of Use'. It was also put forward that 'Perceived ease of use' has a direct influence on 'Perceived Usefulness'. Finally both these beliefs / constructs are hypothesized to be influenced by system design characteristics, represented below as 'External Variables'. This model has known some re-adaptation in the later years and is still being widely used.

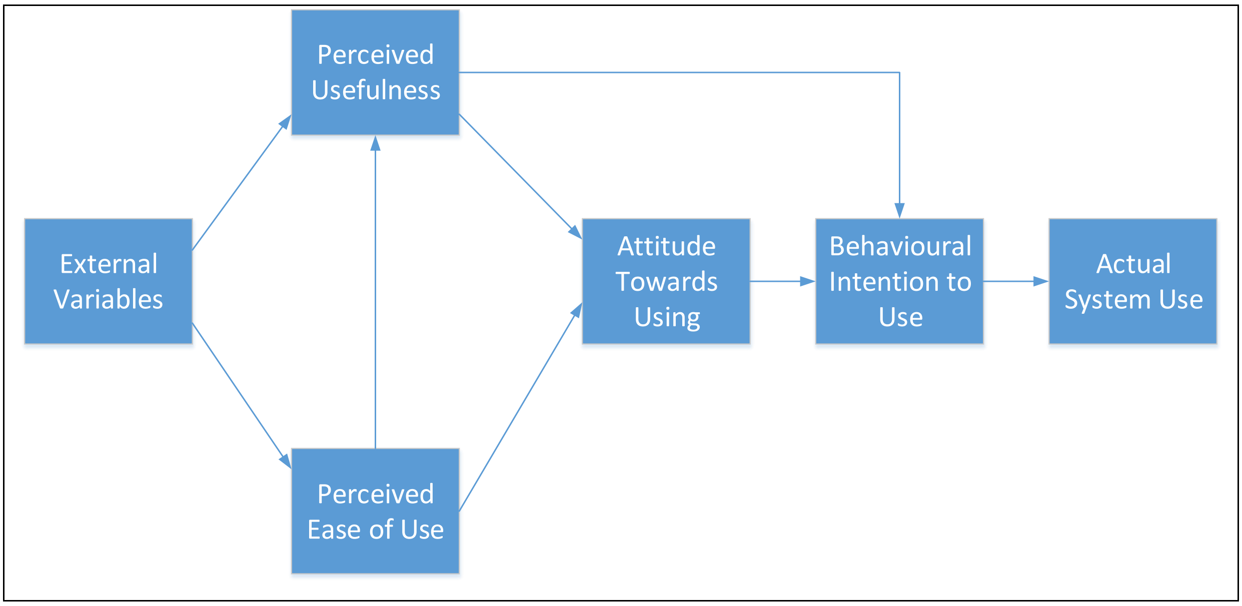


Figure 3. 6: First modified version of Technology Acceptance Model

(Source: Adapted from Davis et al, 1989)

3.5.1 Relevance of the TAM Model in this research

The Technology Acceptance Model (TAM) has been used in research pertaining to the adoption of Technology in Learning. Farahat (2012) uses TAM to identify the determinants of student's acceptance of online learning and to understand how these determinants would shape the learner's intention to adopt online learning. More recently, Esteban-Millat et al. (2018) used an extended version of TAM to have a better understanding of learners' behaviour and attitude towards e-learning environments.

In this study, the TAM Model is used to investigate the acceptance of the SMART Learning Environment by Cybersecurity Professionals in Mauritius. The core idea of TAM is that user's acceptance of technology is determined by his/her behavioural intention, which in turn is determined by his/her *Perceived Usefulness* and *Perceived Ease of Use* of the technology. The TAM model guided the formulation of the questionnaire to investigate the two constructs of *'Perceived Usefulness'* and '*Perceived Ease of Use'*. Davis (1989) defined *'Perceived Usefulness'* as "The degree to which a person believes that using a particular system would enhance his or her job performance." The construct of *'Perceived Usefulness'* was gauged against making the learning process easier, more productive and more efficient. The construct of 'Perceived Ease of use' was assessed against concepts such as operability, navigation, flexibility, effort and clarity.

Legris et al. (2003) concluded that TAM was a powerful tool but had some limitations in the sense that it has to be integrated into a broader theoretical model that involves the use of variables related to social and human dimensions. Several studies (Chung & Tan, 2004; Gao et al., 2016; Hsu & Lu, 2004; Liu et al., 2009; Sánchez-Franco et al., 2007) have also advocated the integration of TAM with other theories and models that take into considerations factors that are not only utilitarian but also include factors that can be of intrinsic motivation to individuals. This might include factors such as flow with regards to technology usage and the models eventually presented in this context have greater explanatory power (Esteban-Millat et al., 2018). Flow can be described as a state where the user feels in complete control of the online tool or environment thereby making the navigation process, the primary reward. This is where the integration of the TAM model with the DSRM framework will help address the inherent limitations of the TAM model. TAM model can be used to evaluate the adoption of the SMART Learning Environment by the learners / trainees, one of the important processes inherent in the Design Science Research Methodology (DSRM).

3.6 Combination of Theories in this Research

The Design Science Research Methodology is used to support the development of the SMART Learning Environment with the Technology Acceptance Model (TAM) Model to guide its evaluation. Activity Theory can be appropriately used in the context of human computer interaction (Blin & Munro 2008). Activity theory can also be used to better understand the goals of E-Learning in an academic setting and in a way that includes all of the major constituents and the influence of social and cultural norms, values, language, and tools (Jonassen et al., 1999). For the purpose of this research, Bloom's Taxonomy will help in designing the learning content so as to ensure that the learning outcomes of the learners / trainees encourage participants reach higher cognitive levels instead of just basic recall of learning.

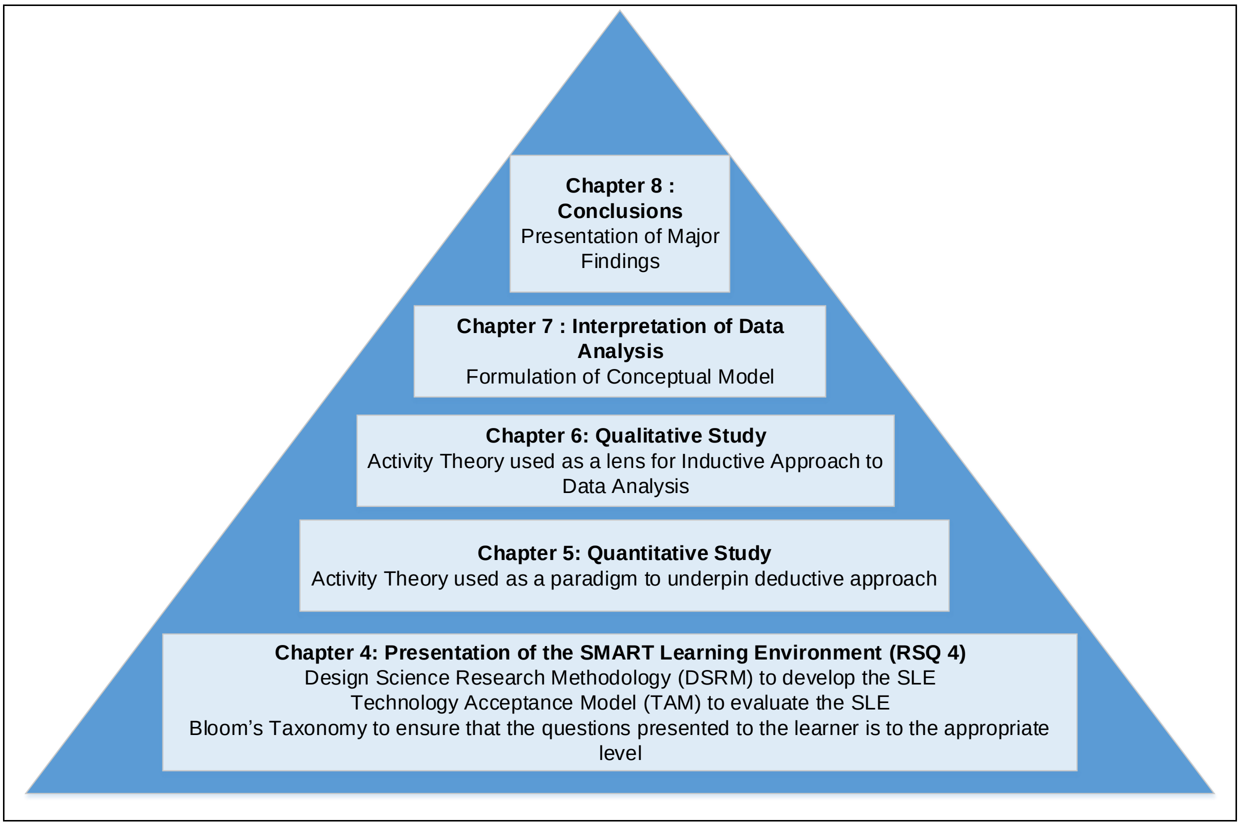


Figure 3. 7: Combination of Theories

(Source: Researcher's own construction)

3.7 Emergent Conceptual Model

Due to the limitations inherent in the individual theoretical models described in the above sections, the researcher deemed it appropriate to come up with a proposed conceptual model which was critically analysed to determine its academic validity. Leshem and Trafford (2007) further stated that a conceptual framework gives coherence to research by 'providing traceable connections between theoretical perspectives, research strategy and design, fieldwork and the conceptual significance of the evidence'.

3.8 Validating the Emergent Conceptual Model through an Expert Reference Group Discussion

Expert Reference Group discussions as a means to collect qualitative data has gained popularity amongst professionals in the IS field though it poses a number of challenges.

Information Systems research investigates people as part of a system, organization or community; and since this research focuses on the interaction of CyberSecurity Professionals with the SMART Learning Environment, Expert Reference Group Discussions offer the possibility of having data that cannot be obtained by any other method. The data collected through such an exercise proves to be helpful in conceptualising and theorising behaviours of individuals as part of a social system (Nili et al., 2017; Belanger, 2012). An Expert Reference Group was convened to collect in-depth qualitative information about how specific chosen professionals in the ICT, Education and Human Resources (HR) fields, perceive the validity of the Conceptual Framework proposed by the researcher and the usefulness of SMART Learning Environments to address the research problem identified earlier. Krueger and Casey (2000) suggest that the number of participants in an Expert Reference Group Discussion may vary depending upon the complexity of the problem under investigation but should be between six and ten participants for the process to be manageable. Indeed the Expert Reference Group Discussion should be large enough to gather a variety of perspectives but it should not be the case that the exercise becomes fragmented and disorderly. Homogeneity of the group, achieved though group dynamics and synergy should be privileged so as to generate rich data. Morgan et al. (1998); Nyumba et al. (2017) suggest that there are four major steps in Expert Reference Group Discussion. This is summarised in figure 3.8.

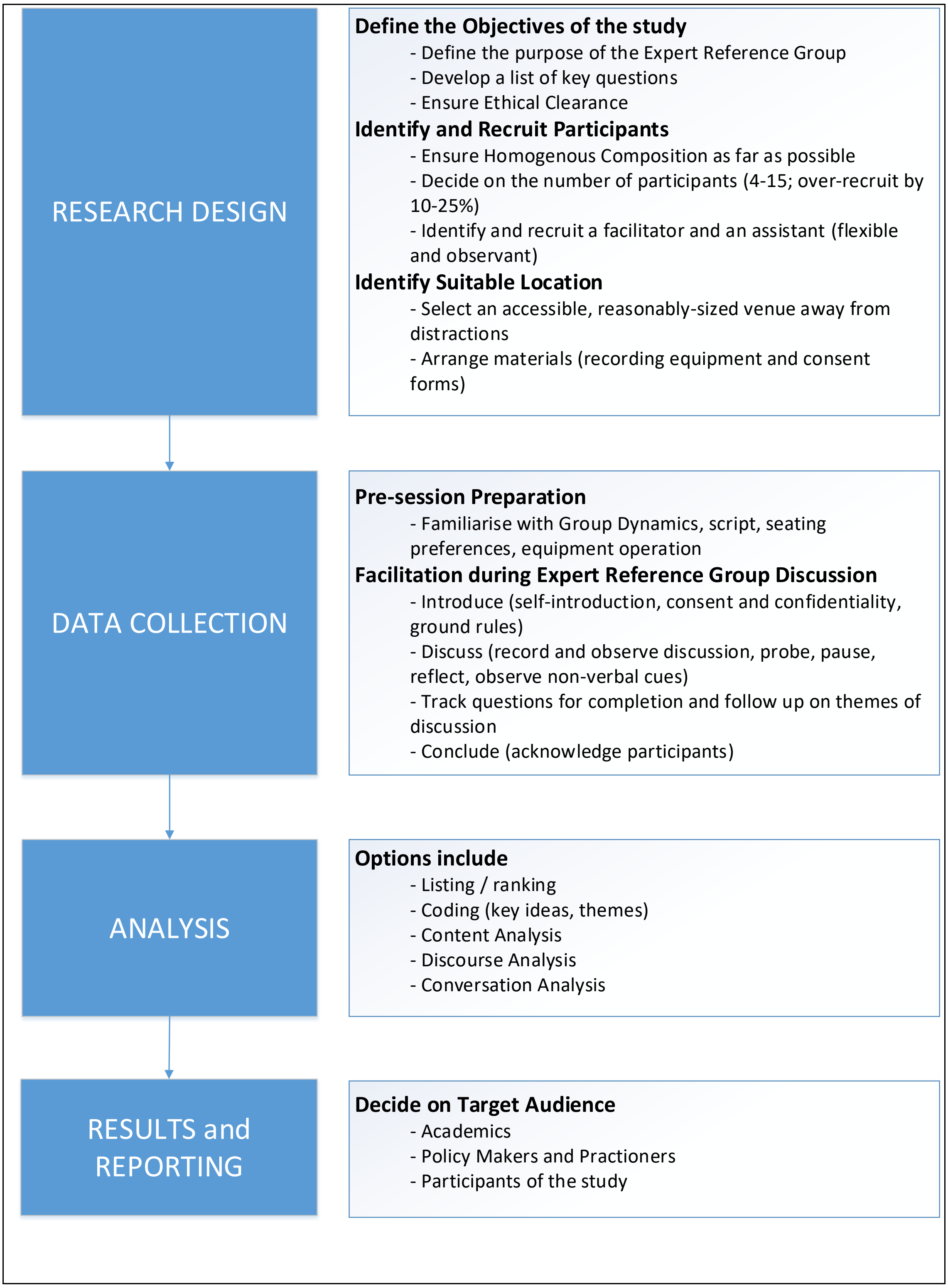


Figure 3. 8: Steps for Expert Reference Group Discussion

(Source: Adapted from Morgan et al. (1998); Nyumba et al. (2017))

In the Analysis of Qualitative Data generated from an Expert Reference Group Discussion, an understanding of the following terms/concepts is important.

Table 3. 3: Terms / concepts useful in an Expert Reference Group Discussion

Terms	Definition
Content area	A content area also termed as a domain is part of texts such as sentences and paragraphs depicting a similar concept, more or less directly related to each other (Elo & Kyngäs, 2008)
Meaning Unit	A meaning unit can be seen as "words, sentences or paragraphs containing aspects related to each other through their content and context" (Graneheim and Lundman, 2004)
Condensation	Condensation, also known as reduction or distillation, is seen as the process of shortening a text without changing the quality of the underlying concepts (Elo & Kyngäs, 2008)
Code	A code is basically a label, name or colour assigned to a condensed meaning unit (Elo & Kyngäs, 2008)
Category	A group of similar codes which may also consist of subcategories (Elo & Kyngäs, 2008)
Theme	"A thread of an underlying meaning through, condensed meaning units, codes or categories, on an interpretative level" (Graneheim & Lundman, 2004)

The literature on to properly plan and carry out Expert Reference Group Discussions is diverse. However, there is little methodological literature about how to scientifically analyse data generated by Expert Reference Group Discussions, especially pertaining to the field of Information Systems (Nili et al., 2017; Grønkjær et al., 2011). Nili et al., (2017) propose the use of a framework for the analysis and interpretation of data generated from an Expert Reference Group Discussion in the field of Information Systems. This framework is summarised in the table below.

Table 3. 4: Framework for analysis of Qualitative Data generated from Expert Reference Group Discussion

(Source: Adapted from Nili et al., 2017)

<table>
<tr><td colspan="2">1.Determine and organize different types of data</td></tr>
<tr><td colspan="2">2.Identify content areas</td></tr>
<tr><td rowspan="4">In each Content Area</td><td>3.Conduct a manifest analysis of content data</td></tr>
<tr><td>4.Conduct a latent analysis of content data</td></tr>
<tr><td>5.Analyze interaction data</td></tr>
<tr><td>6.Integrate the results in each content area (integrate the results obtained through steps 3 to 5)</td></tr>
<tr><td colspan="2">7.Integrate and report the results of all previous steps for all content areas</td></tr>
</table>

A copy of the Discussion Document for the Expert Reference Group can be found in **Annexure C**.

Section B: Research Design

3.9 Research Design

Research design is the set of methods and procedures used in collecting and analysing data to address the identified research problem. These can range from broad assumptions to detailed methods of data collection and analysis. The research design consists three major components namely, a philosophical worldview, strategies of inquiry and research methods (Creswell, 2014). In simple terms, it is a plan or proposal to conduct research. The different options available can be summarised in the diagram below. The selection of a particular research design is guided by a number of factors, ranging from the nature of the problem under investigation, the audience of the study, to the researcher's personal experiences. The approaches used in this research are placed bold, underlined and in capital letters. The sections that follow help to shed light on the different components of research design and ends with a justification of the chosen approaches.

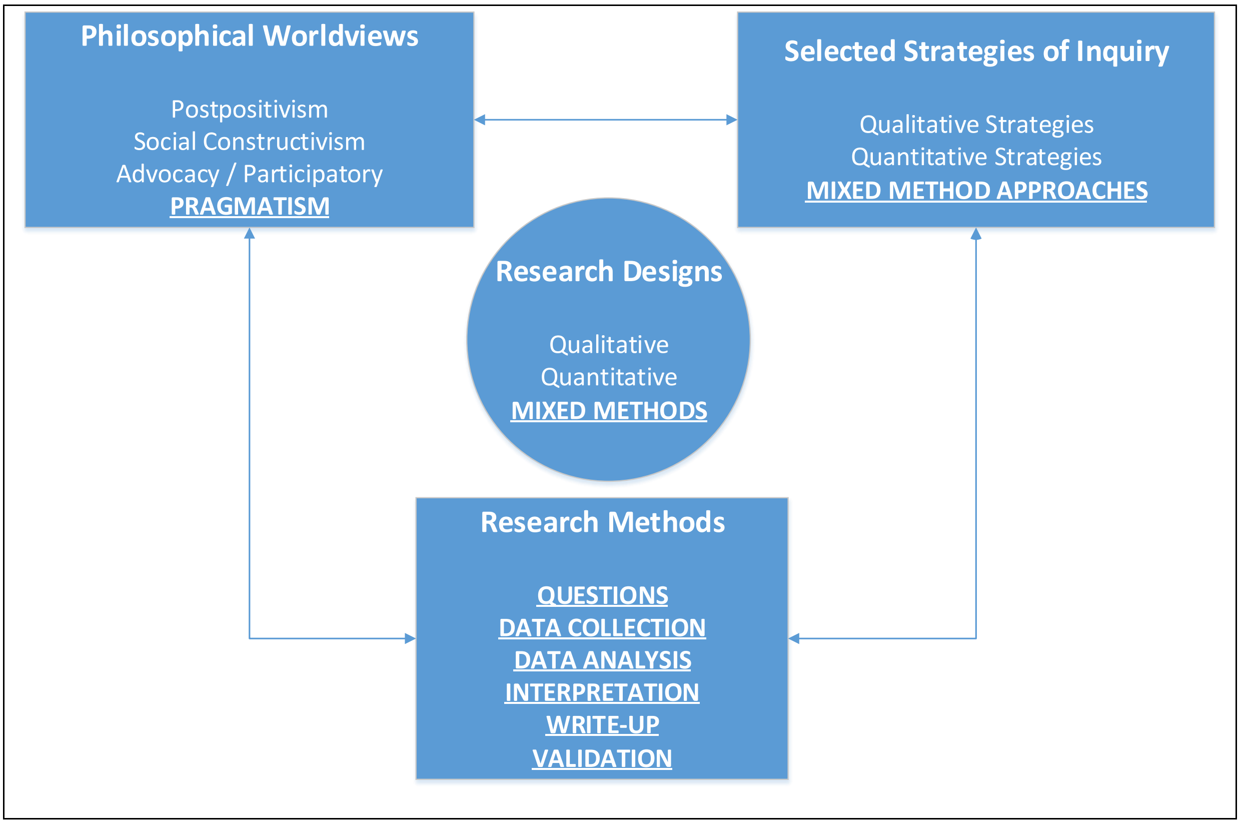


Figure 3. 9: Research Design

(Source: Adapted from Creswell, 2014)

3.9.1 Philosophical Worldview

A worldview or paradigm is a basic set of beliefs that guide action (Guba, 1990). These beliefs have in the past been characterised by different terms, namely paradigms, epistemologies, philosophical assumptions and ontologies. According to Creswell (2014), the philosophical worldview component refers to a general orientation regarding the world, relative to the nature of the research being carried out. Creswell (2014) suggests that there are four worldviews, namely Postpositivism, Social Constructivism, Advocacy / Participation and Pragmatism, applicable in qualitative research. A discussion of each is summarised in the table below.

Table 3. 5: Philosophical Worldview

Worldview	Description
Postpositivism	Researchers engaged in qualitative research use a scientific approach to research which involve a component of logical thinking and empirical data collection. This approach is commonly seen with researchers having prior quantitative research training and is commonly used in fields such as health sciences. In terms of practice, Postpositivism will imply the use of a series of logically related steps and the adoption of rigorous methods of data collection and analysis. One of the basic techniques of positivism includes reductionism, which is about decomposing complex concepts into smaller units that can more easily be studied (Oates, 2010). Replicability is another component of Positivism, where it is believed that an experiment will yield the same result every time it is executed. One of the criticisms of reductionism is that it is argued that certain situations should be examined holistically and contextually and cannot be replicated in other situations. Furthermore, with its mechanistic approach, positivism, may neglect personal experiences and individualities. Creswell (2014), does not refer to positivism but to postpositivism, which represents the thinking after positivism and aims to identify the causes of outcomes and thereafter do a thorough assessment.
Social Constructivism	Constructivism is based on the belief that individuals strive for an understanding of the world they live in and work. The participants' views of the situation and interactions with others are also important, hence the concept of social constructivism. This approach encourages the researcher to look for the complexity of views instead of narrowing the meanings in a few categories or ideas. Instead of starting with a theory (as in

	Postpositivism), researchers generate or inductively develop a theory or pattern or meaning (Creswell, 2007). Participants are encouraged to construct the meaning of a discussion, typically forged during interactions and discussions. Constructivist researchers also focus on the specific contexts in which the individuals live and work, listening attentively to what they have to say, and eventually constructing an understanding of the cultural and historical setting of the participants. Constructivist researchers understand that their own experiences and background 'shapes' their interpretation and intend to make sense out of the meaning others have about the world. In practice, this is achieved through the design of open-ended and general questions that would facilitate interactions and discussions.
Advocacy / Participation	It in the 1990's, discussions amongst researchers arose whereby it was put forward that Postpositivism imposes theories and structural laws that do not reach out to the marginalised groups or individuals. Social constructivism, on the other hand, was seen as not going far enough into advocating for action to help individuals. So a worldview which would contain an action agenda in view of reform and to change the lives of participants and the institutions in which they live and work had to be thought of. Besides, the challenges faced by the marginalised individuals and groups were pressing and it was seen as vital to study issues such as racial issues, feminist perspectives, oppression, alienation, domination and suppression. Researchers wanted to become a 'voice' for these marginalised individuals and this is where advocacy / participation as a worldview gained momentum. This approach has been endorsed by a number of researchers, namely by Kemmis and Wilkinson (1998) who further

	depicted some key features of this worldview. Kemmis and Wilkinson advocate the importance of participatory action as being recursive, with the intent of bringing change in practices. An action agenda for change is normally one of the outcomes of an advocacy / participatory study. Kemmis and Wilkinson (1998) further stress on the fact that this worldview is important so as to help individuals free themselves from constraints found in language, media, relationships of power in an educational setting and work procedures. Other researchers who have embraced this worldview include Heron and Reason (1997). The term participatory is often used in conjunction with action research. The latter involves a research whereby the participants contribute towards bettering their personal practices and also gives rise to a situation whereby the researcher frequently acts a practitioner-researcher, investigating the evolution of his/her product (de Villiers, 2012).
Pragmatism	Pragmatism focuses on 'actions, situations and consequences, rather than antecedent conditions' (Creswell, 2014). This is in contrast with postpositivism, which involves more of a scientific approach. Pragmatism can be viewed as a worldview where the focus is on finding practical solutions to problems and an approach that evaluates beliefs and theories in terms of the success of their practical application. Pragmatists do not believe in a single truth but rather view truth as 'what works at the time' (Cherryholmes, 1992; Murphy, 1990). Since pragmatism believes in the fact that there is no absolute unity or truth, the research methods involved are very often a mixed one, involving both qualitative and quantitative.

3.9.2 Selected Strategies of Inquiry

Creswell (2014) argues that there are three strategies of inquiry, namely, qualitative, quantitative and mixed mode approaches. These strategies of inquiry or research methodologies will eventually shape the research design of a study.

3.9.2.1 Qualitative Approaches

Qualitative research is a means of investigating and understanding the meaning an individual or group assign to a human or social problem. Here, the researcher very often asks descriptive or exploratory questions. Non-numerical data is collected in the form of texts, diagrams, images and audio recordings from interview transcripts. Qualitative analysis very often involves textual analysis of verbal and written data. (Merriam, 2009, Creswell, 2014 and Mouton, 2004) describe the common qualitative strategies and analysis techniques as ethnography, phenomenology, grounded theory, critical qualitative research, qualitative case study, narrative analysis and Content Analysis. This is discussed in the table below.

Table 3. 6: Qualitative Approaches

Qualitative Approach	Description
Narrative Analysis	Commonly used in a context of mode of inquiry with special focus on stories told by individuals. The procedures consists of studying one or two individuals, collecting data through the analysis of their user stories. The information collected is then retold in a chronological way by the researcher.
Phenomenology	As compared to a narrative study that examines one or two individuals, phenomenology or phenomenological research involves the study of the lived experiences of a group of individuals about a phenomenon described by the participants.
Grounded Theory	Grounded Theory is an approach derived from sociology where the researcher comes up with a general, abstract theory of a process, action or interaction grounded in the views of the participants (Creswell, 2014).

Qualitative Case Study	In this method of inquiry, the researcher develops an in-depth analysis of a case, event, program, activity, individual or process. A variety of data collection procedures are used over a sustained period of time (Yin, 2012) and the case studies are bounded by activity and time.
Ethnography	Ethnography is a method of inquiry in which the researcher investigates the shared pattern of behaviour, actions of a cultural group and language in a natural setting over a spanned period of time and through observation and interview, data is collected.
Content Analysis	Content Analysis analyses the content of the text or document to refer to words, themes, meanings, pictures or patterns (Mouton 2004). Krippendorff (2004) defined content analysis as "a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use".

The steps that will be used for Content Analysis, from planning to presentation can be summarised in the figure below.

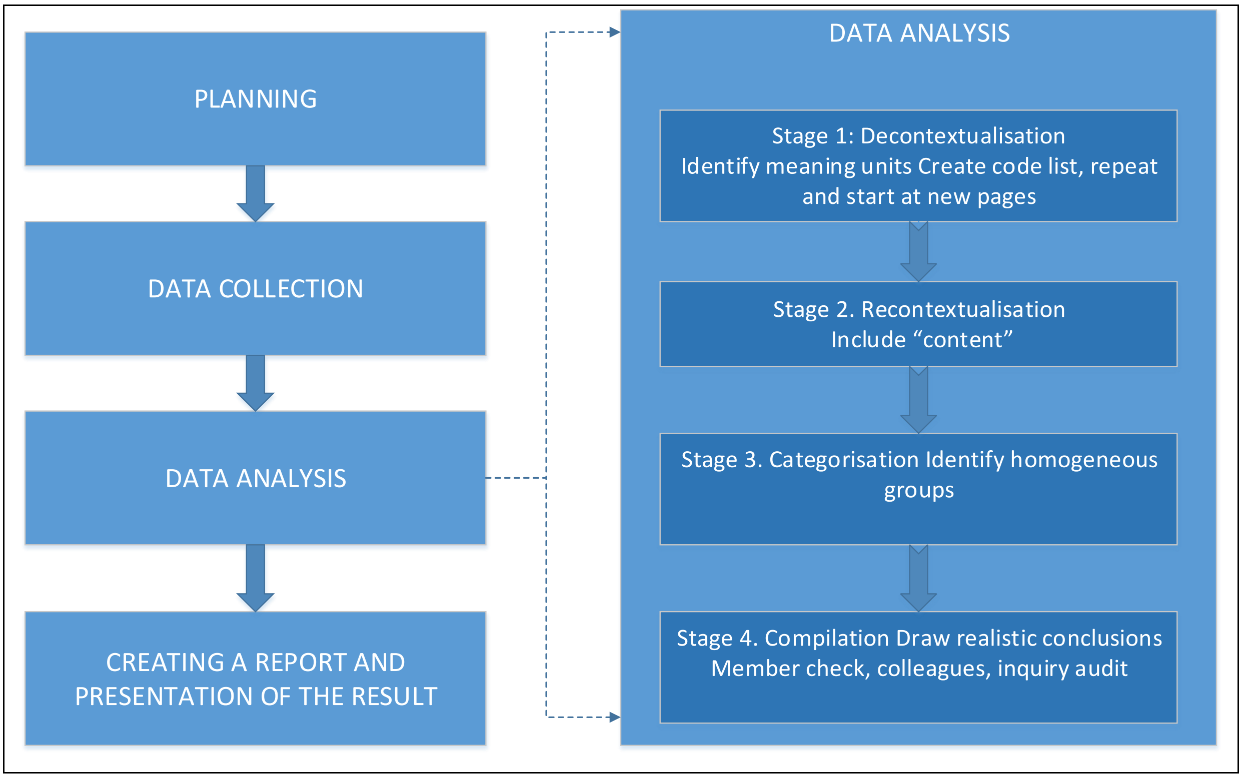


Figure 3. 10: Overview of the process of a qualitative content analysis

(Source: Adapted from Bengtsson, 2016)

3.9.2.2 Quantitative Approaches

A quantitative approach is usually associated with finding evidence to either support or reject hypotheses that have formulated at the earlier stages of the research process. Quantitative studies result in data that provides quantifiable, objective, and easy to interpret results. The design of most quantitative studies also helps to ensure that personal bias does not impact the data collection and analysis. Quantitative data can be analysed in a number of ways. There are four main types of quantitative research designs: descriptive, correlational, quasi-experimental and experimental.

3.9.2.3 Mixed Method Approaches

With the legitimacy of both qualitative and quantitative approaches discussed above, mixed methods research has gained momentum and is widely accepted and positively viewed by researchers. The mixed method approach combines the strength of both qualitative and quantitative approaches

3.9.3 Research Methods

This research employs both qualitative and quantitative approach as research methods. In the qualitative approach the researcher seeks to find meaning to a phenomenon from the views of participants whereas in a quantitative approach the researcher tests a theory by specifying a narrow hypothesis and the collection of numerical data to support or refute the hypothesis (Creswell, 2014). Both methods have data collection tools as described below. The research will be conducted in ICT Companies in Mauritius which encounter problems with training, up-skilling and re-skilling of Cybersecurity professionals.

3.9.3.1 Quantitative Data Analysis

Surveys will be used to collect data from a sample of respondents, enabling the data to be codified, normally into quantitative form. The sample chosen will be allowed to submit anonymous responses, thus improving the likelihood of honest answers (Kellett, 2005).

3.9.3.2 Population Size and Sampling Frame

As identified by the Board of Investment (2016), the ICT-BPO Sector employs 23,000 people in Mauritius with 2,323 professionals in the IT Services sub-sector which consists of employment in Data Centres, Disaster Recovery, Business Continuity, Process, Consultancy, Training, ICT Trade and Networking. This research will focus on the up skilling and reskilling of ICT professionals in the area of Cybersecurity where there is a dire need of professionals (BOI, 2016). Currently, 25% of ICT Professionals in the IT Services sub-sector are in the area of Cybersecurity, which results in the population size for this research being 581 (BOI, 2016). This study focuses on large ICT-BPO companies, which account for 20% of the total number of ICT-BPO Companies in Mauritius. Indeed the larger companies find it more difficult to maintain a trained and skilled ICT work force.

3.9.3.3 Sample size

For the pre-test, 20 ICT Professionals in the area of Cybersecurity were used to give initial feedback during the development process so that their constructive feedback can be used to refine the system through an iterative process. This forms part of the DSR process and these 20 ICT professionals were thereafter excluded from the sample of ICT Professionals chosen to evaluate the system. These 20 professionals were practitioners from the ICT Industry operating at various levels in the field of Cybersecurity in Mauritius. After the development of the SMART Learning Environment was completed, a survey (Annexure C) was completed by a sample of 83 respondents to evaluate the effectiveness of the proposed SMART Learning Environment. The sample size was derived from a population size of 581 with a Confidence Level of 95% and a Confidence Interval of 10%.

(Calculated from https://www.surveysystem.com/sscalc.htm)

3.9.3.4 Sampling strategy

Purposeful Sampling will be used to target ICT Professionals in the area of Cybersecurity operating at different levels (Information Security Officer, Information Security Analyst, Information Security Consultant, and Chief Information Security Officer)

3.9.3.5 Questionnaire

There were two sets of questionnaires for this research.

- Pre-test Questionnaire to help in the DSR Process to further refine the SMART Learning Environment through an iterative process. The responses collected were mostly qualitative and targeted 20 respondents, who were thereafter excluded from evaluating the final SMART Learning Environment. A copy of the pre-test questionnaire is found in **Annexure D**.

- Survey Questionnaire to be used by a sample of Cybersecurity Professionals in Mauritius to evaluate the proposed SMART Learning Environment. 63 respondents were targeted here. A copy of the survey questionnaire used for evaluating the proposed SMART Learning Environment is found in **Annexure E**.

3.10 Data Analysis

3.10.1 Qualitative Data Analysis

Qualitative data, in the form of interview transcripts, notes, audio recordings, text documents and information obtained through questionnaires, was generated by the Expert Reference Group Discussion, Pre-test Questionnaire and Survey Questionnaire.

3.10.2 Quantitative Data Analysis

For the purpose of this research, a Descriptive Design was adopted, whereby the researcher seeks to describe the current status of a variable or phenomenon. The researcher does not begin with a hypothesis, but typically develops one after the data is collected. Data collection is mostly observational in nature.

3.11 Strategies adopted in this research

The philosophical orientation guiding this research is pragmatism. The essence of this research is to bring something concrete and meaningful to the Cybersecurity community and eventually to the society as a whole. The problem identified in this research is a genuine one, impacting a certain population with cascading effect on the whole of society. The pragmatic view also means that there is no single truth and uses all possible approaches to better understand the problem. This worldview allows the use of a number of strategies to try to find a solution to the problem and encourages the use of mixed method research studies, involving both qualitative and quantitative data collection and analysis.

3.12 Ethical Considerations

Ethical considerations should be at the centre of every research undertaken and its importance should never be underestimated. The focal point of ethics in research is to protect the respondents from harm and safeguard their dignity, anonymity, and confidentially (Naidoo, 2019). The researcher should ensure that at every phase of the research, participants should be safe from harm and protected from unnecessary stress. Unethical research compromises the trustworthiness and validity of the data being collected (Cacciattolo, 2015). This is why the researcher should adhere to a professional code of conduct and should ensure the safety of the participants at any point in time. Hulley et al., (2001) suggest that for ethical research to be carried out, the researcher should ensure that (i) Informed Consent is obtained, (ii) Participants with impaired decision-making capacity are protected and (iii) confidentiality is maintained. For this research, a gatekeeper's permission letter has been obtained from the Ministry of Technology, Communication and Innovation of the Republic of Mauritius (MCTI) and full ethical clearance has been obtained from the University of KwaZulu-Natal (Annexure D and E respectively).

3.12.1 Recruitment of Participants

Recruitment can be seen as the initial dialogue that takes place between the researcher and potential participants prior to the initiation of the consent process. The recruitment process involves a process of identification, targeting and enlistment of participants (Patel et al., 2003). In this stage, the researcher should ensure that the interest from the part of the potential participant is triggered and that the latter is sufficiently informed about the importance of this study and its expected contributions. Whilst choosing participants, the researcher needs to ensure that the participants and the sample chosen are representative of the target population.

This research involved the recruitment of three batches of participants. The first batch of participants was meant for an Expert Reference Group where 6 participants were recruited, 2 participants from each of the three fields of ICT, Education/Training and HR. Here the selection of the participants was done according to their expertise in their relevant field and the possible contribution they could bring as a homogenous and dynamic group in understanding the rationale behind the research undertaken by the researcher. The second batch of participants involved the purposeful recruitment of 20 Cybersecurity Professionals operating at various levels in the field of Cybersecurity. This approach was used since these persons would be able to positively contribute to fine-tune the SMART Learning Environment. This fits in the approach of DSRM where constructive feedback is obtained and the system is iteratively refined until fit for testing by a sample of the population of Cybersecurity Professionals. Indeed, this sample of Cybersecurity Professionals, 83 as calculated above is a purposeful sample which aims at being representative of the whole target population of Cybersecurity Professionals in Mauritius.

3.12.2 Informed Consent

Informed Consent is the process by which a fully informed participant voluntarily decides to participate or not to participate as a research participant in the study. At any point in time, the participant remains free to withdraw from the study, without having to give justifications. Informed Consent was obtained by the researcher, congruent with UKZN guidelines and as suggested by Patel et al. (2003).

3.12.3 Confidentiality and Anonymity

The participant's right to confidentiality is a central issue and should not be compromised (Nishimoto, 1998). Confidentiality is indeed essential to maintain the trust relationship between the researcher and the participant and the integrity of the research undertaken as a whole. Anonymity entails the fact that identifying information about individual participants such as name, address, email address are not collected. Thus, the research cannot link individual responses with participants' identities.

3.12.4 Protection of study participants

In this research, the study participants were protected in a number of ways so as to ensure the trustworthiness and integrity of the research being undertaken and so as to abide by the principles of ethical research as a whole. Firstly the participants participated on a voluntarily basis to address a problem of national interest and they were free to withdraw from the study at any point in time without having to give any explanation. An informed consent form and an information sheet was used to was used and the participants were reassured that the data collected would be kept confidential, anonymised and would be securely kept for a period of 5 years after which it would be disposed of. Participants were also informed that data collected would be used only for the purpose of this research and that they would be participating in their own personal capacity and not binding their views to the institutions where they are currently working. But above all, the researcher has to ensure that a feeling of trust and belongingness is established between the researcher and the participants.

3.13 Emergent Conceptual Model

As discussed in section 3.1 and 3.7, a Conceptual Model is obtained by the researcher joining concepts together in a cohesive way so as to explore a research problem and to further propose a model that better represents concepts in the research as compared to existing theoretical models (Regoniel, 2010). The existing theoretical frameworks that were used to create the conceptual model are Design Science Research Methodology (DSRM), Bloom's Taxonomy and Technology Acceptance Model (TAM).

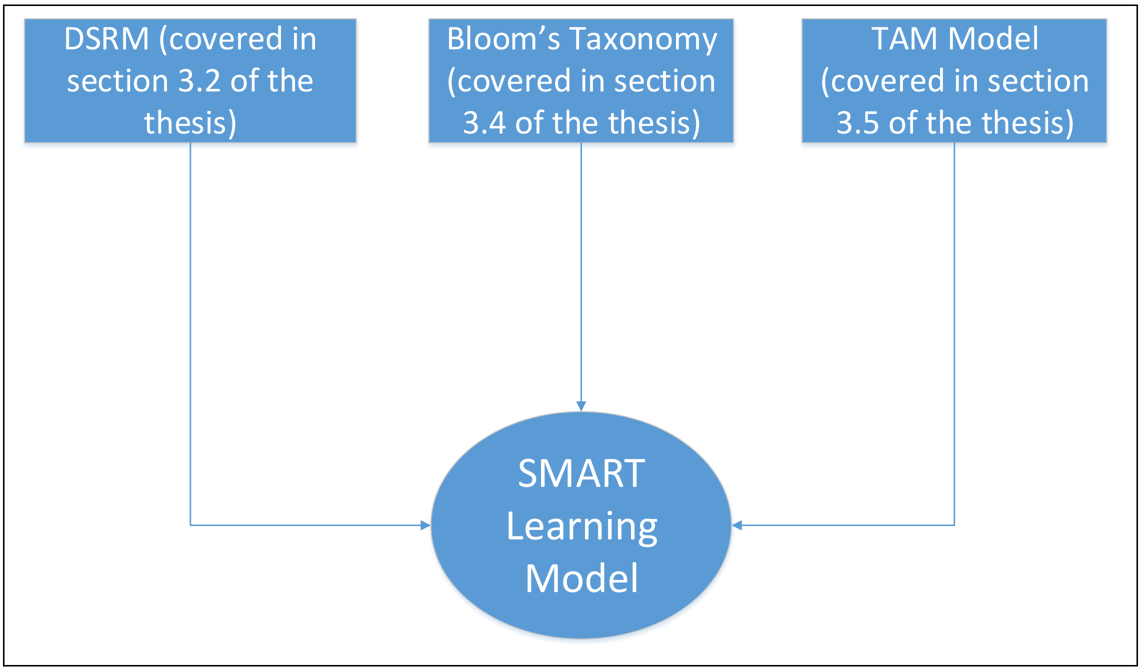


Figure 3. 11: Conceptualisation of SMART Learning Model

(Source: Researcher's own construction)

The Emergent Conceptual Model proposed by the researcher is shown in Figure 3.12 and is thereafter named the SMART Learning Model. At this stage, adding more details to the Conceptual Model in terms of over-elaboration and over-parameterization is not necessarily going to make the model a better one. In fact, it has been designed in a simple way so as to be able to represent the processes effectively. The SMART Learning Model has been specifically conceptualised for the purpose of this research. The research problem under investigation was a complex one and using existing theoretical frameworks was not sufficient. The emergent conceptual framework provided the researcher with a wider angled analytical lens to convey the diverse problem situations in this research.

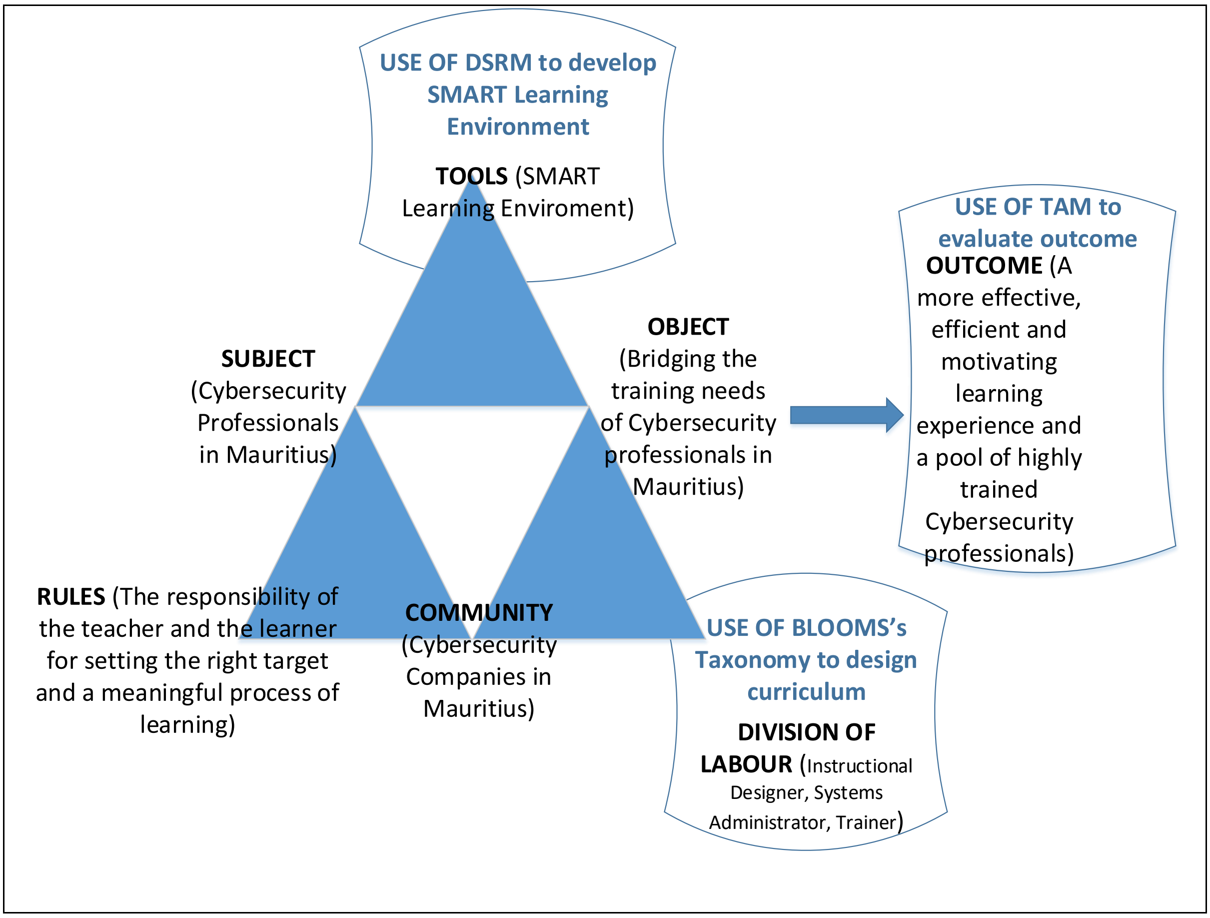


Figure 3. 12: Emergent Conceptual Model (SMART Learning Model)

(Source: Researcher's own construction)

At this stage, brainstorming with all the different stakeholders involved in this research is important. This is where the Expert Reference Group Discussion has its whole importance and significance.

3.14 Validating the Emergent Conceptual Model through an Expert Reference Group Discussion

An Expert Reference Group has been used to gather information on the problem identified in this research and to validate the proposed conceptual model described in section 3.12.

The members involved in the Expert Reference Group included two professionals from each of the following fields; ICT, Education/Training and Human Resources (HR) each, acting in their individual capacity and not representing any organisations or governmental agencies. The participants will for the sake of anonymity be henceforth referred to as Respondents 1 and 2 (from ICT), Respondents 3 and 4 (from Education / Training) and Respondents 5 and 6 (from Human Resources). The selection of the participants was purposive and not necessarily representative of the population. It was based on the idea that each of the participants had something to say about the topic and would be comfortable talking to researcher. The group discussed the problem identified in this research to reaffirm and/or refine the problem. A discussion protocol was established and the discussion was moderated by the researcher himself. A note-taker was also assigned, not only to take notes and to document exchanges but also to observe the non-verbal interactions.

The participants in the Expert Reference Group Discussion were expected to be able to positively contribute to further shed light on the usefulness of the SMART Learning Environments. Group Dynamics and synergy was encouraged by the researcher. It was observed that with the setting up of a homogenous group, richer and deeper data as compared to one-to-one interviews was generated. It was also observed that the discussions were spontaneous and that large amount of qualitative data was generated. At times, the facilitator had to refocus the discussion whilst maintaining a conducive environment which would encourage the participants to share their knowledge and experience. During this stage, the researcher had been careful to ensure that the discussion was not dominated by any participant.

3.14.1 Data Collection

The qualitative data collected was thoroughly analysed for trends, convergence and useful insights. According to Yin (1989), data analysis consists of several phases, namely examining, categorising and tabulating in order to address the initial goal of the study. Data Collection and Analysis can be a challenging task, taking into consideration the volume of qualitative data that is generated. Robson (1993) suggests that one of the central aim is to reduce data. Data was collected using Otter software, which proved to be very useful. It allowed for the possibility of recording and then easily transcribing the data collected.

Data can also be classified broadly into two categories, content data and interaction data (Onwuegbuzie et al., 2009; Nili et al., 2014). In this context, content data has been obtained by analysing the transcripts and interaction data is the data that is derived from observation gathered by the researcher and the note-taker. Interaction data gathered through observation can be one participant agreeing, disagreeing or challenging the views of one or more participants. Other researchers (Nili et al., 2017) argue that data can be in the form of verbal and non-verbal. Verbal Data can be seen as communication taking place in the form of words and sentences whereas non-verbal data can be seen as communication taking place through gestures, facial expressions and loudness or pitch of voice.

3.14.2 Data Analysis

As soon as the participants left the room, the researcher together with the note-taker had a 20 minutes debriefing session to consider what has been observed and share the highlights. The next step was to decide on what to transcribe and also to what extent to transcribe. The analysis of the transcripts has been viewed from three perspectives. Firstly it involved paying attention to individual views and perceptions of a specific individual, paying attention to the words used as well. Secondly, it involved paying attention to the views of the homogenous group as a whole and thirdly paying attention to the interaction between the group members.

To be able to make sense out of the qualitative data collected from the Expert Reference Group Discussion, the researcher needs to immerse himself / herself in the data and 'live' the data (Moser and Korstjens, 2018). The researcher has reviewed the transcripts to collect insightful and legitimate findings and in view of having a deeper understanding of the problem under investigation. The transcribed texts were then analysed using Nvivo which helped the researcher organise, analyse and find useful insights from the large amount of data collected. To facilitate the analysis of data, it is important to cross-check that the transcripts are accurate.

3.14.3 Interpretation of Data and presentation of results

The sections below highlight some of the most useful comments gathered during the Expert Reference Group Discussion. The qualitative data collected during this exercise was quite bulky and the researcher has synthetized some of the main points in table 3.6 below. A more detailed version of the comments received are found in Annexure H. The constructive comments received during the Expert Reference Group Discussion reinforces the problem statement elaborated by the researcher and gives further encouragement towards the use of a SMART Learning Environment to address the problem under investigation.

Section 1:

Table 3. 6: Summary of Results of Expert Reference Group Discussion

Theme: Relevance of the SMART Learning Environment to address the research problem		
Subtheme 1: Expressing the problem situation	**Subtheme 2:** Possibility of addressing the problem through current means available	**Subtheme 3:** Appropriateness / usefulness of the proposed SMART Learning Environment
- There is a serious mismatch between the skills and expertise produced by our education system and the needs of the Industry. One such example is that the increasing number of unemployed graduates on one hand (in the field of agriculture, sociology, language studies and others) and on the other hand, a severe demand of IT	- MOOCs which were supposed to bring a revolution in the field of education with a cascading effect in the ICT Industry has not really been effective. *(Respondent 1)* - MOOCs completion rate has been distressingly low. This can perhaps be accounted to the fact that the concept of sage-on-the-stage works to a	- The idea of providing personalised learning materials to Cybersecurity Professionals through intelligent techniques looks interesting. It may address the problems raised so far during the discussion. Going forward with the idea of using SMART Learning Environments for continuous up-skilling of ICT professionals can prove to be more effective as compared to

professionals at all levels of the IT Industry *(Respondent 2)* - The future growth of the ICT Sector of Mauritius, one of the pillars of the economy, is at stake due to the shortage of skilled labour. *(Respondent 2)* - Indeed some IT companies cannot expand their activities. *(Respondent 1)* - The Government of Mauritius has acknowledged that unemployment amongst young graduates has taken an alarming proportion. *(Respondent 4)* - Clear case of mismatch and if not addressed as soon as possible will be disastrous for the ICT Industry. *(Respondent 4)* - It is being observed that there are some IT graduates who have the necessary academic qualifications / degrees but who are not able to deliver and work as expected because they lack	certain level but after that the learners would want more individual attention and materials that are more adapted to their specific maturity and expertise level. *(Respondent 1)* - Online training can be seen as a solution but the problem remains the fact that the training needs of each of these Cybersecurity professionals remain different. One may get bored with learning materials that they see as too easy or elementary and another one may get discouraged and lost with training materials that they perceive as too difficult." *(Respondent 4)* - Regular Up-skilling and training via face-to-face sessions prove to be quite costly, especially in the corporate world. Besides, providing release from work for these professionals and being able to plan and coordinate all this, requires enormous effort. *(Respondent 3)*	the existing techniques. *(Respondent 5)* - The Government of Mauritius envisages to position Mauritius as a pioneer in the field of AI in the region and has even created an AI Council at National Level (Mauritius Artificial Intelligence Council. Mauritius has been striving hard to move from a middle-income economy and is striving hard to become a developed economy. The topic of SMART Learning Environment is directly in line with the vision of the Government and such a research will definitely have the keen interest of the Government of Mauritius. *(Respondent 1)* - The SMART Learning Environment, once developed for this specific research, can easily be tweaked to provide training in other areas such as finance, tourism and textile, each of the three areas mentioned above, being pillars of the Mauritian Economy. *(Respondent 6)*

certain technical skills and aptitudes. *(Respondent 3)* - Stressing again on the necessity for professionals to follow appropriate technical certifications and to undergo continuous professional development and constant up-skilling to keep up with the fast-evolving pace of the ICT Industry. *(Respondent 3)*	- We must try to think for the coming five years and plan ahead. Current means of education and training have reached a kind of saturation point where we need to come up with new tools and techniques for running the new development lap as far as education and training is concerned. *(Respondent 6)*	- The flexibility provided by such a learning environment is interesting especially if we consider that the target consist of working professionals who have a very busy agenda. *(Respondent 3)*

Section 2: Additional technological concepts/features that can be suggested to better align the use of SMART Learning Environments for up-skilling and re-skilling of Cybersecurity professionals in Mauritius.

This section highlights the different comments received by the respondents. A discussion is deemed important by the researcher since some of the comments will be used as input to refine the emergent Conceptual Model proposed in Section 3.13. After analysing the different comments of the respondents in their respective boxes, the researcher gives a brief interpretation and discussion of the comments received.

Box 1: Using Technology just because it looks trendy?

'The digitalization of Education is pervasive and occurs at all levels, whether it is in the teaching process or at an administrative level. In this era of Big Data and Cloud Computing, the technological opportunities are immense but the learner's needs are central. We should not be using technology just for the sake of using the technology or because it looks trendy. Technologies should be used to address a problem statement and to provide a viable solution. In other words, Technology should be seen as a facilitator/enabler and should be used to provide a learning environment that is engaging, motivating and which has the capacity of providing rich interactions.' (Respondent 2)

Discussion: The learning community is surrounded by a plethora of technologies, but using technology for the learner's growth is the key. Otherwise, using technology just for the sake of using technology is meaningless. Using Technology should, in the end, bring an improvement in the quality of not only the content, but also an improvement in the processes involved. For example, asking the learner the same questions that he/she could have been asked in a classroom by a teacher and asking the same questions in a digital learning environment, does not bring an increase in the quality of the training.

Discussion: The field of Education faces enormous challenges. Artificial Intelligence as it has been discussed in Chapter 2 can bring a whole new dimension to Education and to Education Technology (EdTech) more specifically. AI can help in reshaping the future of education by addressing the issues raised so far. Recently, in the national Budget of Mauritius (2018-2019), the Minister of Finance announced the creation of a Mauritius Artificial Intelligence Council, comprising of professionals from the public and private sector, who will be helped by professionals/experts from abroad in view of creating an ecosystem conducive for AI to grow. This clearly shows the interest of the Mauritian government to position the country as an AI hub for the region in view of developing expertise for the country and the region at large. Besides as described earlier, the Republic of Mauritius faces a pressing need to train ICT professionals in an effective, motivating and engaging way. The solution can be envisaged to be found at the juncture of AI, Professional Training and Educational Technology.

Box 2: Artificial Intelligence

'A recent report by Price Waterhouse Coopers (2018) mentions that Artificial Intelligence could contribute around $ 15.7 USD trillion to the world economy in 2030, which is more than the current combined GDP of India and China. This report has also stressed on the fact that 45% of total economic gains in 2030 will be derived from product enhancements, something that will be achieved through personalization and attractiveness. AI is expected to automate certain tasks and processes so as to boost up the productivity of enterprises. Soon, AI will be pervasively used in all spheres of life, and Vladimir Putin rightly said, AI is not only for Russia but for humankind as it comes with colossal opportunities. Education Technology (EdTech) on the other hand, seen as the ecosystem of innovators applying technology to education is a market worth around $5 trillion per annum, besides cutting across all sectors and contributing billions to economies. The idea of applying AI to Education Technology is fully justified and can bring along unique opportunities as it has been mentioned in terms of personalization and providing a

Box 3: Learning Analytics

'Online Learning Environments have been existing for years. However, one aspect of the learning process that is important, is to be able to monitor the progress/evolution of the learner in the learning environment. At times, certain learners are at risk and can feel isolated and demotivated. These learners perhaps require double attention and they are perhaps those learners who would have dropped out in MOOCs, accounting for the very high drop-out rate in MOOCs. Interestingly, nowadays, we have the concept of Analytics, whereby we can discover, analyse and communicate meaningful trends in data and apply these trends in decision making. The same concept can be used in the teaching and learning process, where it is termed as Learning Analytics. Learning Analytics can help determine who are those learners who are lagging behind and what remedial action to take so as to make them reach the required level. The notion of personalization, we were talking about, also fits here, where the progress of the learner is being closely monitored and personalized remedial action is

Discussion: There are a number of definitions of Learning Analytics but they all related to how learners' and institutional data can be collected and analysed in view of developing statistical analysis and predictive modelling in view of creating intelligence upon which learners, teachers and administrators can base themselves to change academic behaviour and to improve the learning process and experience. Learning Analytics can help identify the 'disconnected' learners (or outliers) and help in bringing them on the right track. The framework proposed by Greller and Drachsler (2012), described in Chapter 2 is interesting as it considers Learning Analytics from a holistic point of view, considering all the necessary dimensions for its effectiveness. The six dimensions include Technologies, Educational Data, Objectives, Stakeholders, Competences and Constraints. An understanding of Learning Analytics would only be superficial and shallow if the underling Learning Theories are not understood. Learning Theories help to guide in terms of the data to be collected and the learning analytics approaches to be adopted. For example, researchers investigating Self-Regulated Learning (SRL) may wish to focus on the learning sequences (Jovanović et al., 2017) whereas researchers focusing on socio-constructivism might envisage to explore the learner's interaction with other fellow peers and instructors.

Section 3: Comment on other factors that are important for the proper use of SMART Learning Environments in work / business environments.

Box 4: Pedagogy and Learning Theories

'It is good to focus on technology but we have to also understand that the knowledge to be imparted has to be done in an effective way whereby the learner is motivated and the knowledge transfer is done in a way whereby the processes, contexts and interactions are privileged. This is what we may term as pedagogy or the science of teaching. Very often, we tend to over-emphasize on the technological aspects whilst neglecting other important aspects such as psychological ones. In an online context as this one, the term e-pedagogy is more appropriate. E-pedagogy is still in its infancy but is rapidly gaining grounds as it agreed by e-learning professionals that though e-learning has been so popular and trendy, there is a definite gap to be filled as far as pedagogy is concerned. Currently much

Discussion: Very often it is seen that e-learning or technology-enhanced learning environments are being operated by e-learning IT administrators or IT professionals. The questions that has to be asked is whether the learners in an online or SMART Learning Environment dispose of the adequate pedagogical, psychological or emotional attention and interaction that is normally required in a teaching process. Some scholars refer to pedagogy as the science and art of teaching. (Baldiņš, 2016) refers to pedagogy as educational and learning theory and practice and is seen as a scientific branch analysing the unity of theory and practice. Instructional Design and Pedagogy are closely linked and are in some way or the other linked to Learning Theories. Learning Theories are basically well-defined set of principles about how learners acquire / absorb, retain and recall knowledge. Major learning theories include behaviourism, cognitivism and constructivism. Behaviourism views the learner as a blank slate and skills/knowledge acquired can be viewed and observed. In other words, it can be said that the learner has learnt something new when he or she is able to perform a new behaviour consistently and visibly. (Dennen et al., 2018) describes behaviourism as a theory focused on learning as a persistent change in observable behaviour. Cognitivism, like behaviourism, focuses on objective reality that can be taught. However, in contrast to behaviourism, cognitivism focuses on internal processes of the brain by trying to understand what piece of information will be stored in long-term memory and later on retrieved for use in short-term memory. Constructivism, on the other hand, relies on constituted nature of human experience. (Dennen et al., 2018) describes constructivism as a learning theory whereby people create their own unique meaning based on their sensory-based experiences. At a later phase, being able to integrate and reflect on these acquired experiences fits in the rationale of Constructivism. The criticism of these three learning theories is that they have their roots and that they reflect learning in a different era, way back to the nineteenth century, at a time, where learning was done more in a face-to-face fashion and where learning materials were static. Learning in this contemporary era of technology and technological tools requires a new dimension where memory-intensive tasks can be offset and where it is understood that technology is not only shaping our learning process, but our whole lives. Siemens (2005), thereby suggests Connectivism as a fourth theoretical approach to learning. Technology indeed can indeed alter or 'rewire' our brain and connectivism involves an approach where ICT is inextricably interwoven and whereby it is understood that the learner, besides requiring a certain level of literacy, needs to have a certain degree of maturity.

Discussion: For any learning to take place, there be some specific goals set, against which performance can be benchmarked. Specific targets, criteria, standards, acquired skills, just to name a few factors, help to determine and define the goals. Feedback, basically is information about how the learner's present state (of learning and performance) relates to these standards and goals (Nicol and Macfarlane-Dick, 2006). In such a context of self-regulated learning, formative assessment in view of generating constructive feedback is essential. It is important for learners to understand that feedback is given to bridge the gap between the learning goals initially set and the current level of the learner.

Box 5: Feedback

'*Being able to provide instant feedback to the learner and to be able to track his/her learning growth/profile brings a whole new dimension to quality of the training being dispensed and to the inherent processes of the teaching and learning taking place. With the current teaching and learning process, providing accurate and timely feedback to the learners is not always possible. It is expected that one of the features of the SMART Learning Environment is some component that can provide feedback and recommend on certain measures to be taken by the learner for his/her eventual progress.'* (Respondent 3)

Summary of Expert Reference Group Discussion Findings

The Expert Reference Group Discussion carried out has been a tedious process but it has been able to reaffirm the problem statement described in the earlier chapters of this research. It has also been providing some useful insights about how to better the proposed solution. One interesting element that has cropped up during this exercise and that is worth pondering on, is the use of technology to address an issue and not just for the sake of using technology. Very often, it is believed that novel technologies will be able to address all the problems encountered. This is commonly referred to as the Silver Bullet Syndrome. Other key elements to retain out of this Expert Reference Group Discussion is that Artificial Intelligence, Learning Analytics, Pedagogy, Learning Theories, Instructional Design, Feedback and Recommendation Systems might be some potential tools, techniques and concepts to consider in the design and implementation of the SMART Learning Environment.

3.15 Finalised Conceptual Model

After the Expert Reference Group Discussion carried out and after discussion with the different stakeholders present during this exercise, a finalised conceptual model is presented in Figure 3.13.

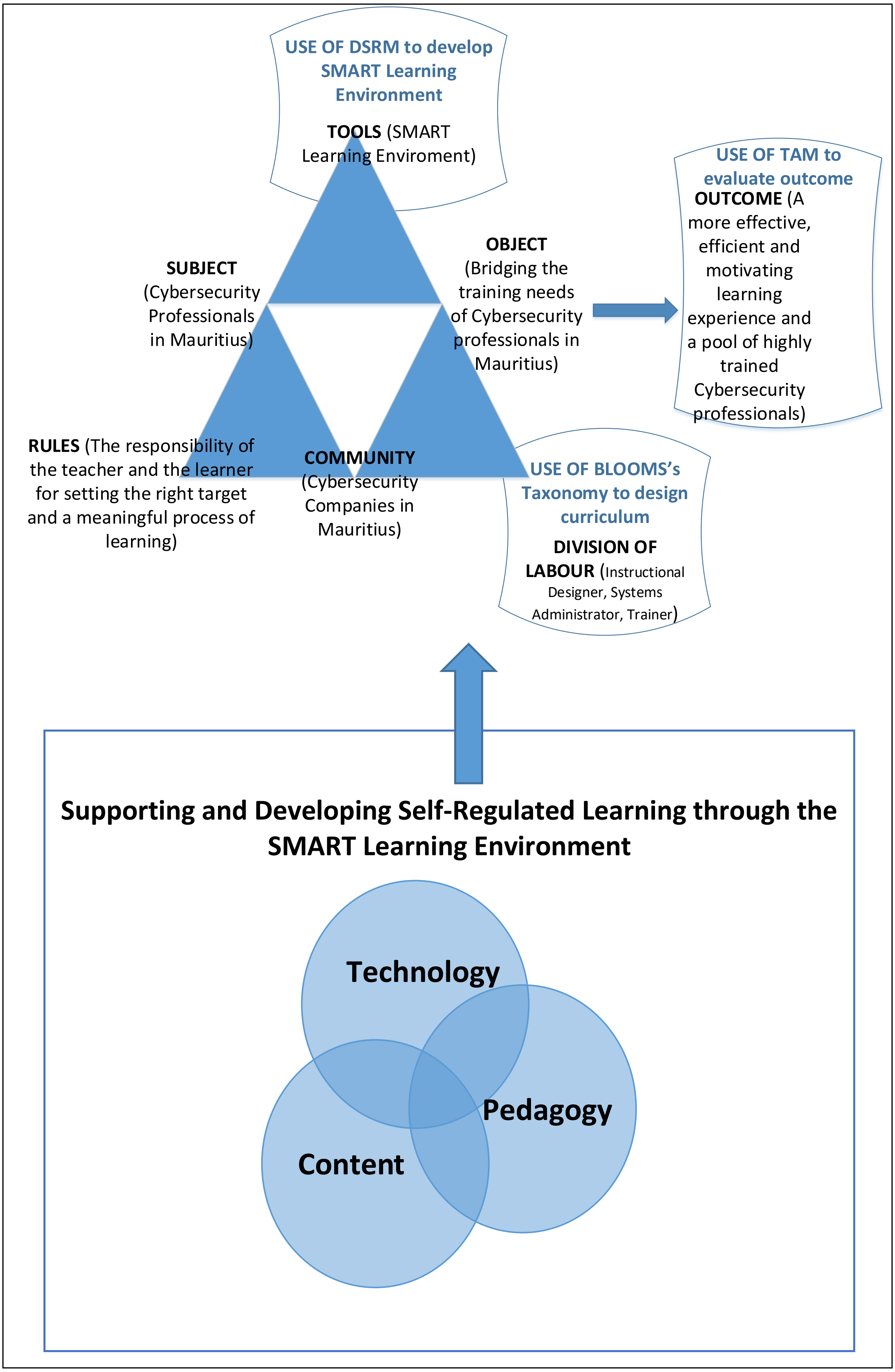


Figure 3. 13: Finalised Conceptual Model (SMART Learning Model)

(Source: Researcher's own construction)

3.16 Chapter Summary

This chapter has been divided into two sections. Section A discusses about the theoretical frameworks that are relevant to this research and section B discusses about Research Design. Section A shreds light on the important theoretical models used in this research, namely Design Science Research Methodology (DSRM), Activity Theory, Bloom's Taxonomy and Technology Acceptance Model (TAM). Section A ends by threading these different Theoretical Models in view of proposing a Conceptual Model which is critically analysed through an Expert Reference Group Discussion. Section B, besides considering an important aspect which is that of Research Design, also touches some ethical considerations pertaining to the involvement of participants in this study. This chapter ends with the discussion of the emergent Conceptual Model elaborated further to the Expert Reference Group Discussion carried out. This exercise enabled the researcher to fully understand the topic under investigation and to have a critical appraisal of the emergent conceptual framework developed by the researcher. A finalised conceptual model was then proposed and accepted. Chapter 4, 'Presentation of the SMART Learning Environment' which follows, deep-dive into the creation of the SMART Learning Environment using mostly DSRM as guiding theoretical framework.

CHAPTER FOUR: PRESENTATION OF THE SMART LEARNING ENVIRONMENT

"It's not about what you know....It's about what you do with what you know that matters". Unknown

4.0 Introduction

This chapter presents the SMART Learning Environment developed using the Design Science Research Methodology (DSRM) theoretical framework which is a widely adopted framework for the development of Information Systems.

4.1 Introduction to DSRM

DSRM was utilised primarily as a process model to guide the development of the SMART Learning Environment and assess its effectiveness in addressing the training needs of the Cybersecurity professionals in Mauritius. An overview of the process adopted is presented below through the lens of each DSRM stage namely:

- Identify Problem & Motivate
- Define Objectives of a Solution
- Design & Development
- Demonstration
- Evaluation
- Communication

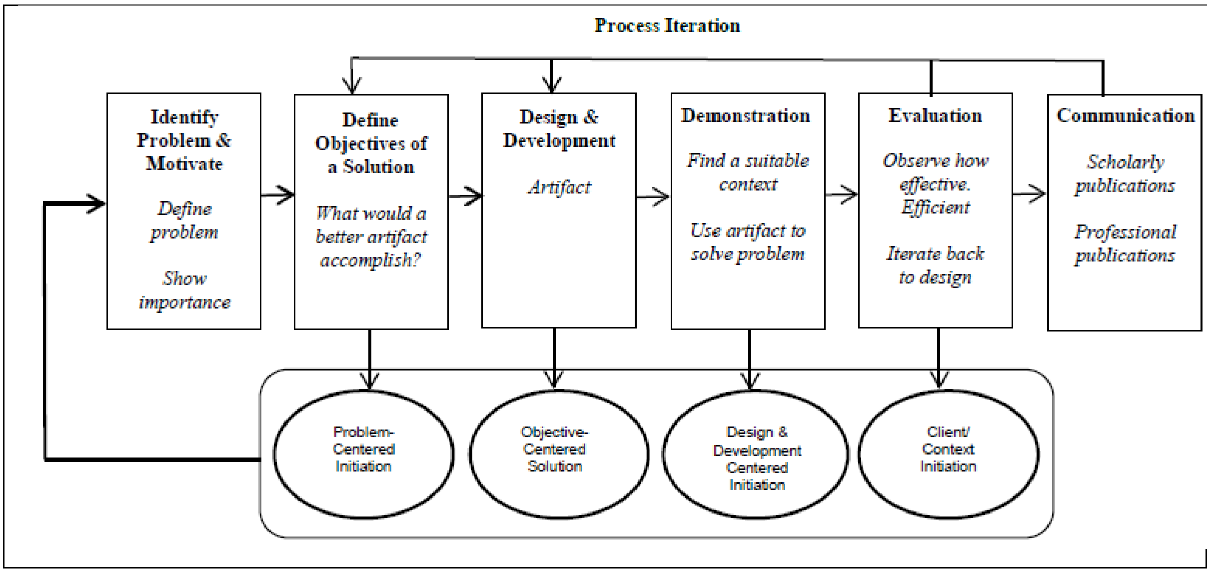


Figure 4. 1: Design Science Research Methodology Process Model

(Source: Extracted from Peffers et al. 2007)

This approach to developing information systems has been encouraged by a number of researchers (Vaishnavi et al., 2017; Gregor and Hevner, 2013; Adebesin et al., 2011; Hevner et al., 2004).

4.2 Stages of artefact development through the lens of DSRM

4.2.1 Stage 1: Identify problem and motivate

While Technology-enhanced Learning has progressed substantially since its introduction, a number of challenges still remain. As identified in Chapter 2, there is often lack of **engagement** from the learners. E-Learning courses also present higher dropout rates due to the fact that distance education may create a sense of **isolation** in students, who can feel disconnected from the other students, the instructors and the university (Juan et al., 2009). MOOCs have been recognised as one of the disruptive innovations in the field of education (Jacoby, 2014) and still there is a lack of understanding of how students engage in the courses delivered over MOOC platforms (Anderson et al., 2014; Ortega-Arranz et al., 2019). The high dropout rate on most MOOCs is the biggest challenge faced by online education providers (Tseng et al., 2016).

Personalised and Adaptive Learning presents an opportunity to provide customised learning opportunities tailored to the individual needs of each learner. This type of learning may contribute to improve the learner's learning outcomes and boost motivation and engagement

(Tseng et al., 2016). Chapter 2 also depicted a comparative study between Adaptive Learning, U-Learning and SMART Learning and suggest that SMART Learning offers a number of advantages over even Adaptive Learning and U-Learning (Hwang, 2014).

The possible features of a SMART Learning Environment (described in Chapter 2) would be most adapted to bridge the training needs of Cybersecurity Professionals in Mauritius. This research not only brings Technology-Enhanced Learning to the forefront of Research but also attempts to make use of a proposed SMART Learning Environment to address a pressing need of the Republic of Mauritius. Indeed, ICT is a pillar of the Mauritian Economy and this sector remains a buoyant and growing one for economic growth and employment in Mauritius (HRDC, 2017). However it is being observed that "skills mismatches in the ICT labour pool are a particular concern given the importance of this sector in the Government's growth strategy." (HRDC, 2017). Even the World Bank Group (2017) has recognized this mismatch by stating that "employer surveys suggest that the ICT sector is facing a labour shortage that is expected to continue or worsen over the next five years, and for which the key factors are a lack of sufficient work experience and low qualifications in both technical and soft skills."

4.2.2 Stage 2: Define objectives of a solution

The following objectives were defined in Section 1.5:

- Explore the training needs of Cybersecurity professionals in the ICT Sector of Mauritius
- Explore the effectiveness of the current learning methodologies in bridging the training needs of ICT Professionals in Mauritius
- Analyse how SMART Learning Environments providing personalisation of Learning Contents operate.
- Analyse the different Intelligent Techniques available for implementing SMART Learning Environments
- Design, Develop and Evaluate a framework for a SMART Learning Environment
- Assess the effectiveness of the SMART Learning Environment in providing Continuous Learning for Cybersecurity professionals in the ICT Sector of Mauritius as compared to traditional Technology Enhanced Learning

4.2.3 Stage 3: Design & Development

Core Components of the proposed SMART Learning Environment

Research into SMART Learning Environment is a multi-disciplinary pursuit. It involves Information Systems as well as other socio-scientific disciplines, one of them being Education. It can be said that SMART Education lies at the intersection of Technology, Content and Pedagogy and adopts very much of a human-centric approach. Through the use of certain tools, techniques and pedagogy, the learning experience can be enhanced and the learners are made more engaged and motivated.

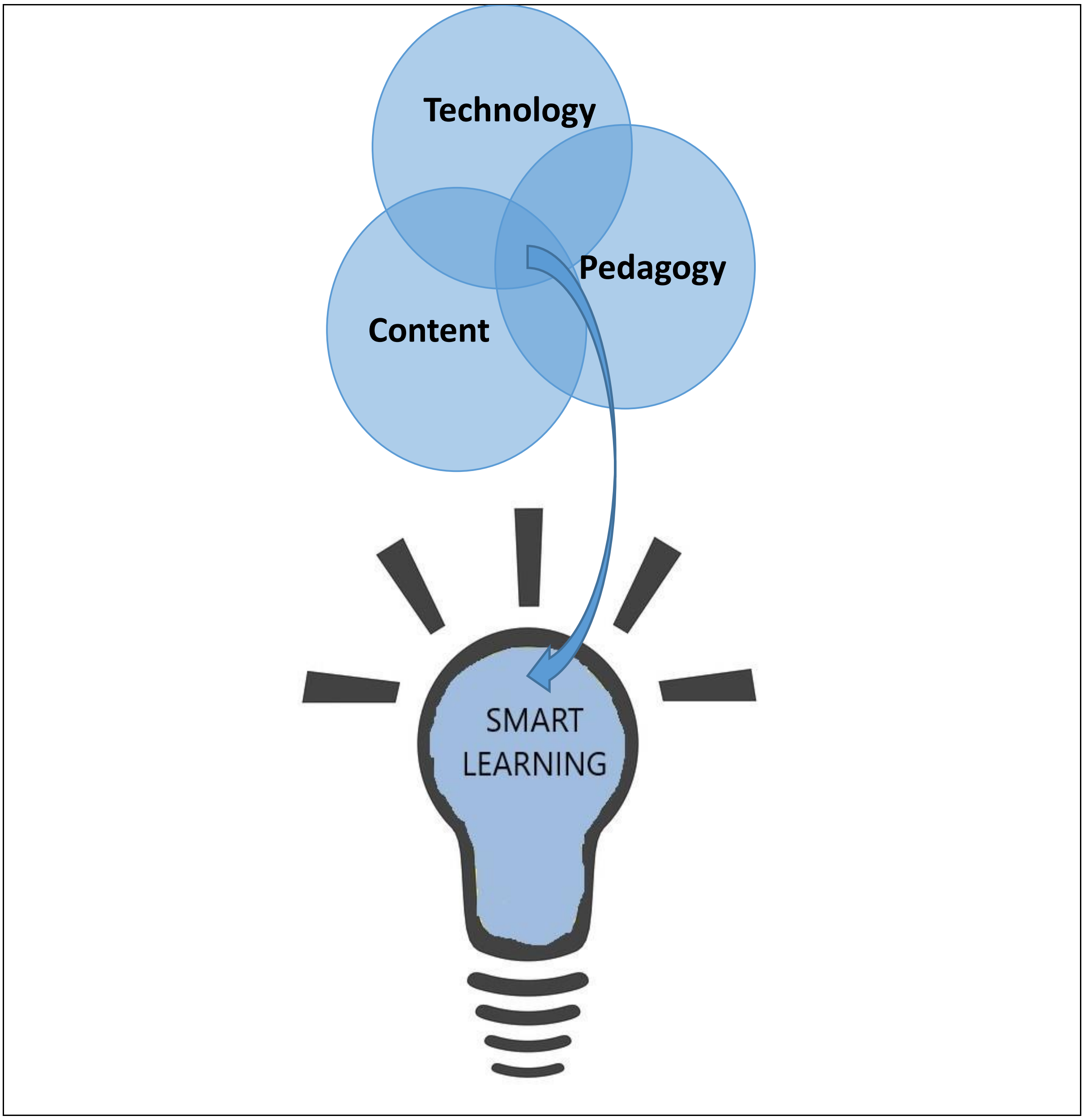


Figure 4. 2: SMART Learning at the intersection

(Source: Researcher's own construction)

This fusion of Technology, Pedagogy and Content is what would make a SMART Learning Environment and whereby the learner would experience self-learning, self-motivation and personalised services. This is shown in Figure 4.2.

4.2.3.1 Design Considerations for the proposed SMART Learning Environment

In the design of a SMART Learning Environment, there are a number of factors and approaches that need to be taken into consideration in order to make the learning process SMART and not only provide a SMART platform to the learner. This introduces the concept of a learning ecology which provides a systemic overview that goes beyond a simplistic techno-centric point of view. It is important to understand that technologies are embedded within learners' habitual life experiences. This perception of a learning ecology views the learner as the main actor, responsible for maintaining social relationships and creating meanings through virtual and physical contexts (Haythornthwaite & De Laat 2012). Gros (2016) argues that there two important considerations in the design of SMART Learning Environment, namely (i) user participation in the design and (ii) provision of support to offer users appropriate feedback.

Participatory Design

The idea behind participatory design is to involve the learner as a partner in the design process rather than just having a passive role as a user. This involvement of the learner in the design process ensures that the SMART Learning Environment is useful and usable. The field of learning design has evolved over the years and now offers a set of methods, tools, systems and models (Goodyear & Retalis, 2010; Mor & Craft 2012; Hernández-Leo et al., 2019) that can empower educators in the design of scenarios that provide richer learning experiences. Design is by nature, collaborative and iterative (Gros, 2016) and eventually requires discussion, collaboration, reflection and critique.

Feedback

Feedback is an essential component in ensuring the improvement of the learner. Traditional approaches of providing feedback to the learner relied on communication with the teacher or mentor. Nowadays, real-time tracking of the learner's activity is possible and the learner can be provided with immediate feedback about his or her learning performance. Learning Analytics can here be exploited to identify behavioural patterns. Two important considerations are here **data** and **visualisation**. The learner needs to have meaningful data that will be beneficial for his or her progress and the proper visualisation should be present to foster self-reflection on the part of the learner (El-Bishouty et al., 2018).

4.2.3.2 Features of the Proposed SMART Learning Environment

The proposed SMART Learning Environment for this research provides the following features:

- Determination of the current Competency Level of the learner
- Evaluation of Learning Performance of the learner done mostly through the use of online tests, activities and tasks.
- Adaptation of Learning Materials
- Visualisation of the progress of the learner
- Recommendation of Learning Tools, Strategies and Feedback for Individual Learners to reach desired level through Learning Analytics.
- Interaction with the learner through Ubiquitous Computing.

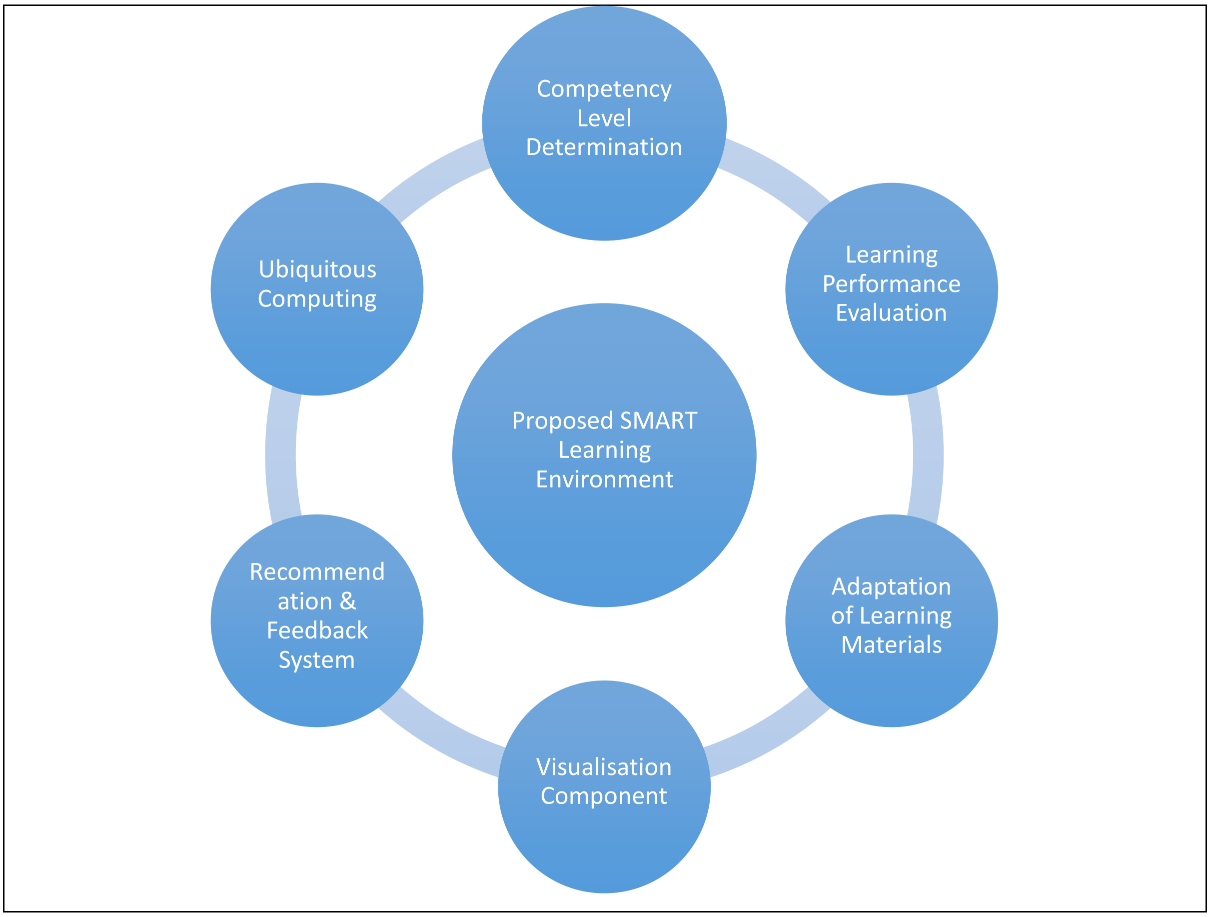


Figure 4. 3: Features of proposed SMART Learning Environment

(Source: Researcher's own construction)

4.2.3.3 Architecture of the Proposed SMART Learning Environment

A three-tiered architecture comprising of Presentation, Domain-Logic and Data Access tiers is proposed. Such an architecture arises naturally from the requirements articulated by the stakeholders and the research itself. This architecture was considered due to its flexibility to cope with changing requirements. Indeed the modularization of the user interface, domain logic and data storage layers enable the modification of one part of the application independent of other parts. Independent tiers can be modified, upgraded or replaced without disturbing other parts of the system. For example, the learning content materials can easily be changed or updated without having to change the domain logic layer and the presentation layer.

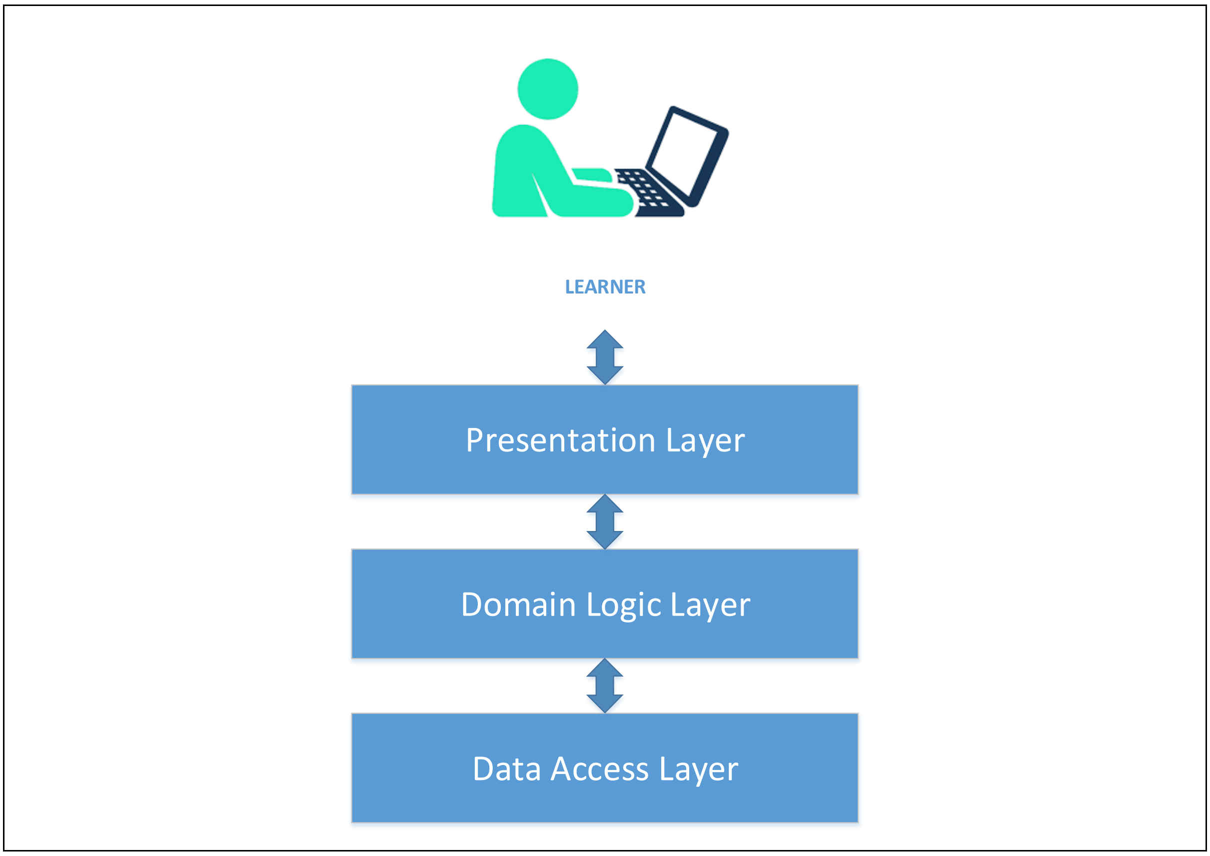


Figure 4. 4: Proposed Architecture of SMART Learning Environment

(Source: Researcher's own construction)

On the **Presentation Layer**, a web interface was designed using the Bootstrap Library. Bootstrap was used since it provides adaptivity to different screen sizes which allows the application to be used on different categories of devices such as laptops, tablets and smartphones. This will encourage anytime and anywhere learning.

The **Domain Logic Layer** will be the 'intelligent layer' that will provide for personalisation of learning content based on the learner's prior knowledge and performance. A machine-learning algorithm will be used for this purpose.

The **Data Access Layer** will consist of databases and learning repositories. Databases will be used to record the learner's activities and details and will thereafter be used to build a profile of the learner. Learning repositories will be used to store the learning materials.

4.2.3.4 Actors in the Proposed SMART Learning Environment

It is important to understand that the training and learning process consists of a set of roles and not necessarily of a set of persons or individuals. Depending on the size of the project, larger projects may require for example, additional instructional designers to achieve the expected output. The actors in the proposed SMART Learning framework consist of the following key personnel and persons as discussed below. It is important to understand that these key actors interact and work together in some learning ecosystem to produce an environment conducive for learning and knowledge transfer.

1) **Content Specialist / subject matter expert**

These are the persons who will help in ensuring the quality of the knowledge to be incorporated in the training program through the proper formulation of learning materials. For the context of this research, content specialist / subject matter experts would be persons well-versed in Cybersecurity and with a proper understanding of the training needs of Cybersecurity professionals. These persons are currently working in the area and besides a degree and a master's degree in Computer Security, have been following professional courses which will help in bringing this hands-on and practical experience which is a must in the Industry.

2) **Instructional Designer**

The Instructional Designer plays a crucial role in the curriculum development process. The latter works in close collaboration with the Content Specialist to collect information on the training needs of the learner and write learning objectives with measurable outcomes. From the very beginning the Instructional Designer works to fully understand the training needs of the learner and design materials that will help the learner progress through the learning process in a measurable way. This is directly in line with the concept of Learner Advocacy. Eventually, the Instructional Designer works towards evaluating the contents to see to it that the outlined standards of rigour, initially set, are met.

3) **Instructor**

The Instructor acts as a tutor or mentor to the group. It has to be understood that though SMART Learning Environments aim at being self-directed and are learner-centred, the Instructor provides this 'human-touch' which is necessary since Online Learning can be tough especially for those who are not accustomed to this way of learning. Communication is important and very often the Instructor acts as a motivator. The Instructor strives towards Constructivist Instruction which is based on the concept that the learner is a naturally active learner willing to construct new personalised knowledge by linking prior knowledge and new knowledge.

4) Platform Support Specialist

The role of the Platform Support Specialist is responsible for supporting the SMART Learning Environment in terms of availability, administration, troubleshooting, security and response time. This role is crucial since it will eventually determine the adoption of the platform by the learners. If the downtime is high or the responsiveness is low, this will discourage the learners from using the platform. The target audience for the SMART Learning Environments are working professionals with a busy agenda and limiting the inconveniences caused in terms of technical failures is essential for the successful adoption of the SMART Learning Environment. This is where platform support specialists have a key role to play.

5) Learner

The SMART Learning Environment provides the opportunity for the learner to become more engaged by having a better control over the learning process. The learner has a pivotal and central role in the SMART Learning Environment and providing personalised learning materials to learners with different aptitudes and skills is expected to boost their motivation, engagement and learning experience. The learner in this particular context are professionals wanting to undergo reskilling or up-skilling in the field of Cybersecurity.

4.2.3.5 Framework of Proposed SMART Learning Environment

The proposed framework of the SMART Learning Environment is further expanded as shown in the figure 4.5 and consists of the modules listed in table 4.1. A modular approach is preferred for a number of reasons. A modular approach brings in a certain flexibility in terms of code reuse, debugging and future modifications.

Table 4.1: Modules of the SMART Learning Environment

	Modules	Description
1	Curriculum Design Module	This module will help content specialists, instructional designers and trainers prepare and set questions to eventually monitor the progress of the learner

2	Initial Competency Level Determination Module	This module will help determine the prior knowledge of the learner
3	Learning Performance Evaluation Module	This module evaluates the learner's performance through the use of online tests and other learning activities. Results of the activities carried out will thereafter be stored for analysing at a later phase.
4	Personalised Learning Module	This module adapts the learning contents, materials and tasks based on the learner's prior knowledge, performance and learning objectives. With the help of this module, the learner will be provided content and activities that would be most appropriate to him or her and would ensure that the learning process is most effective, efficient and customised according to his or her needs
5	Visualisation and Feedback Module	This module will provide, through data collected, appropriate visualisation that eventually would help in delivering timely and appropriate feedback to the learner
6	Recommendation of Learning Tools, Strategies and Feedback Module	The purpose of this module is for Individual Learners to reach desired level through Learning Analytics. This Module will recommend to the learner the most appropriate learning strategies, activities and contents so as to reach desired level and objectives
7	Ubiquitous Computing Module	This will help reach out to the learner and ensure that the learning process can take place anytime and anywhere

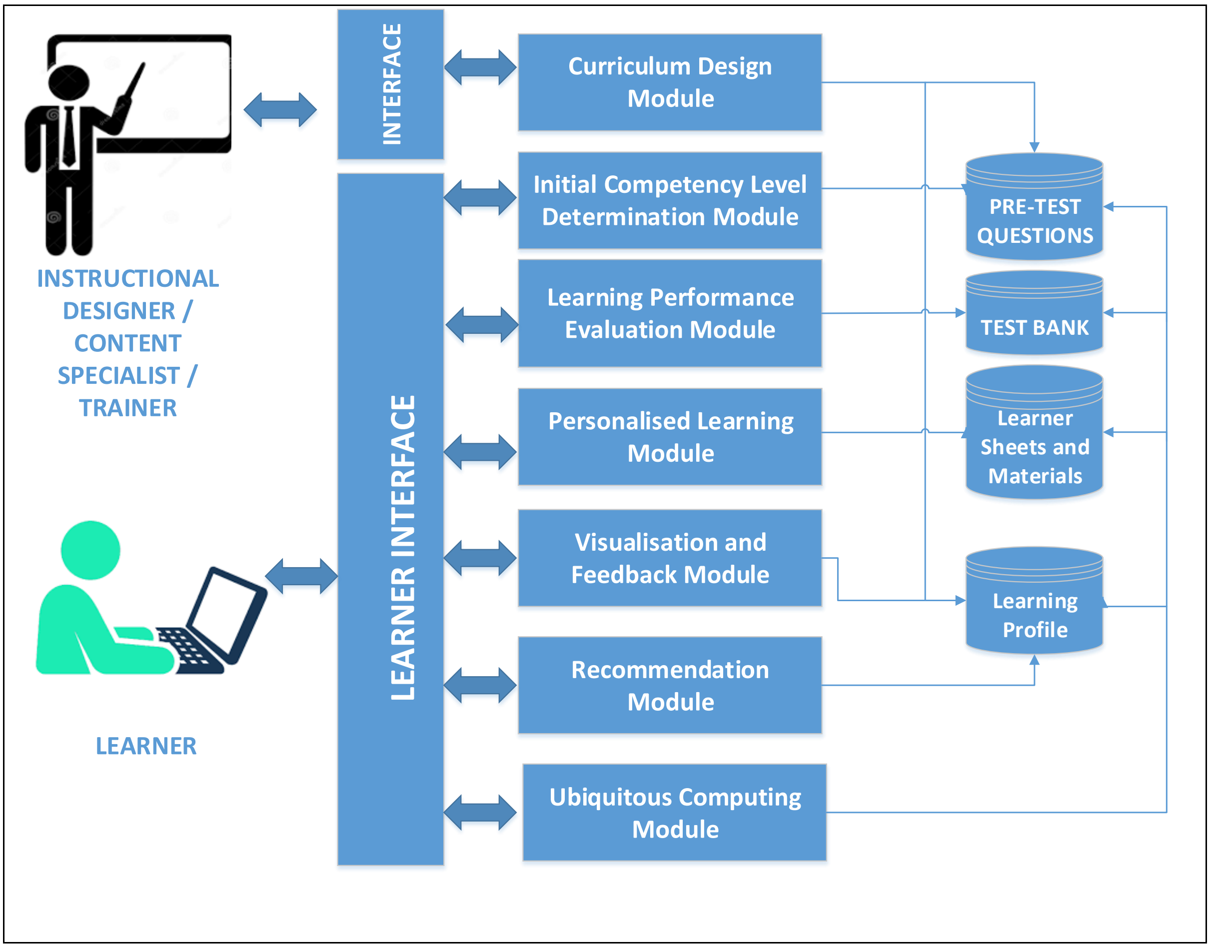


Figure 4. 5: Proposed Architecture of SMART Learning Environment

(Source: Researcher's own construction)

An in-depth explanation of each module is given below

1) **A Curriculum Design Module**

This module is important mostly for Instructional Designers, Content Specialists and trainers to prepare and set questions that would serve as learning materials in the SMART Learning Environment. It has to be also understood that Curriculum Design and Development is a continuous process whereby learning materials, once developed, have to be critically assessed and thereafter revised. The ADDIE model which is a generic model commonly used by instructional designers, has been used. The five phases, as suggested by the name ADDIE itself, consists of the following phases; Analysis, Design, Development, Implementation and Evaluation.

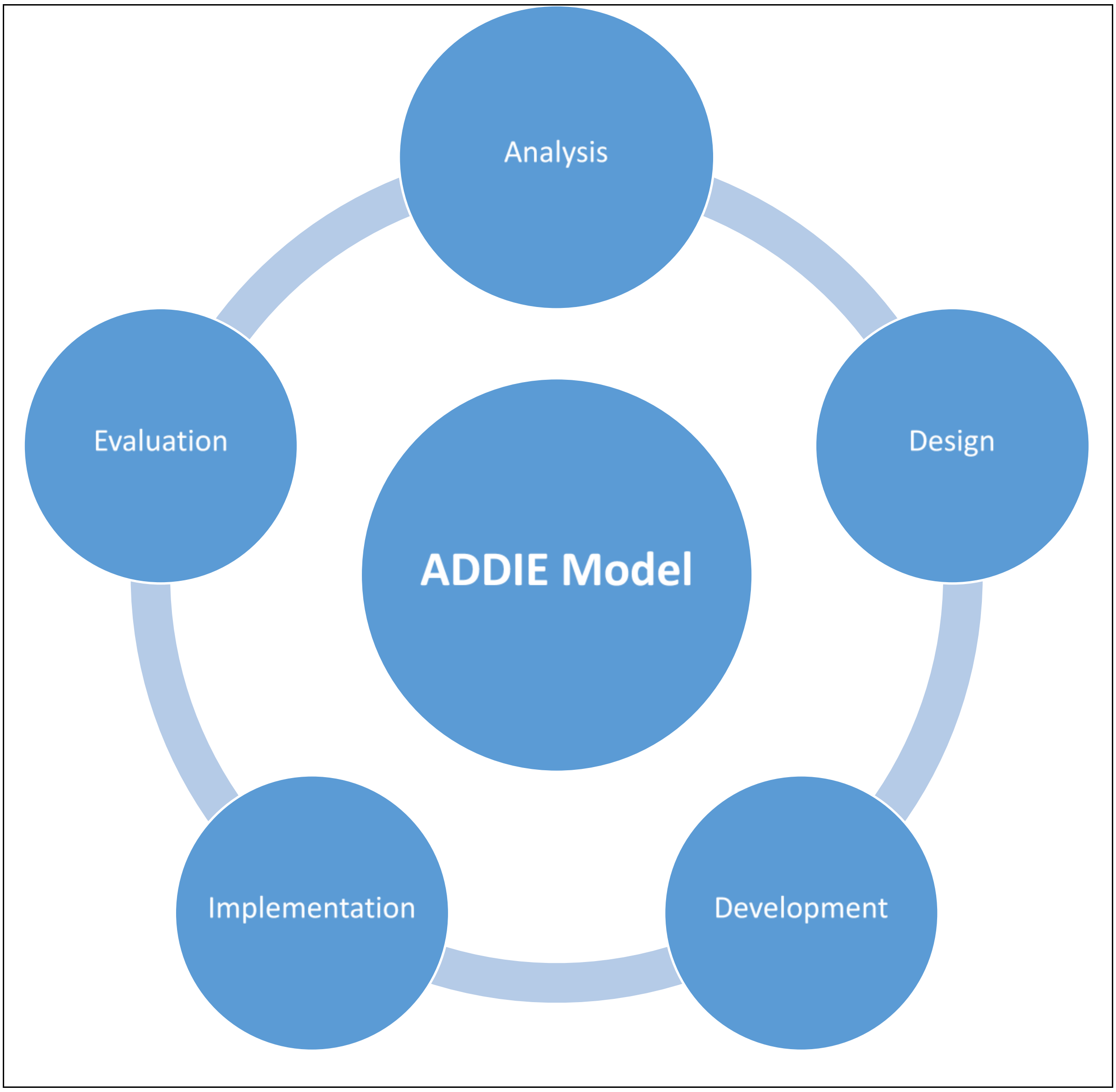


Figure 4. 6: ADDIE Model

(Source: Researcher's own construction)

Bloom's Taxonomy plays a key role in ensuring that the instructional design process is systematic and rigorous and this will eventually determine the quality of the learning materials to be used. The learning objectives and goals defined through the use of Bloom's Taxonomy are important to ensure that the pedagogical interchange between the learner and the instructor is fully understood by both parties and that the process is transparent. Bloom's Taxonomy also encourages higher forms of thinking by the learners which is imperative, especially for working professionals. The same principle can be applied for other areas of expertise such as

Networking, Software Development and many others but for this research, the context is Cybersecurity.

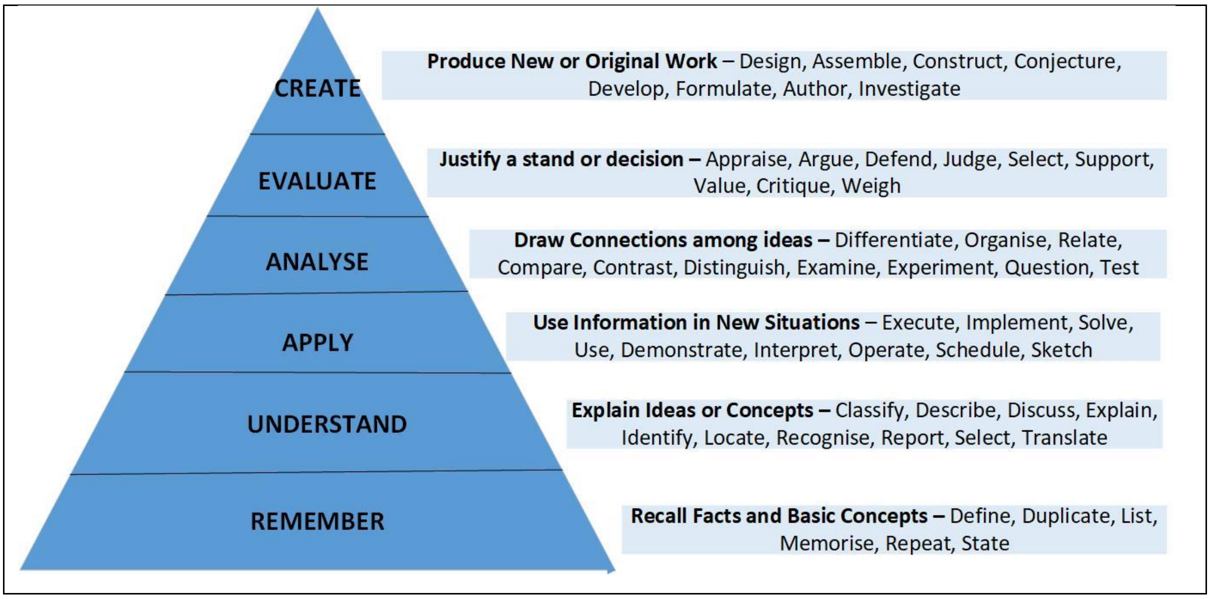


Figure 4. 7: Bloom's Taxonomy

(Source: Adapted from Vanderbilt University Center for Teaching, 2017)

Common professional courses in the field of Cybersecurity include Certified Information Systems Security Professional (CISSP), Certified Ethical Hacker (CEH), Licensed Penetration Tester (LPT), Certified Information Security Manager (CISM), CCNA Security, just to name a few. One common certification that is widely adopted by Cybersecurity Professionals is Certified Ethical Hacker (CEH). This certification is best suited for IT and Information Security professionals who want to broaden their knowledge on Computer Forensics and Ethical Hacking and is a globally recognised Cybersecurity certification. The learning objectives and syllabus of the CEH V10 certification has been synthetized in the table below.

Table 4.2: Outline of CEH Certification

(Source: Adapted from CEH v10, EC-Council, 2019)

Chapter ID	**Topic**	**Outline**
CEH1	Introduction to Ethical Hacking	Key issues plaguing the information security world, incident management process, and penetration testing.

CEH2	Footprinting and Reconnaissance	Various types of footprinting, footprinting tools, and countermeasures.
CEH3	Scanning Networks	Network scanning techniques and scanning countermeasures.
CEH4	Enumeration	Enumeration techniques and enumeration countermeasures.
CEH5	Vulnerability Analysis	Perform vulnerability analysis to identify security loopholes in the target organization's network, communication infrastructure, and end systems. Various types of penetration testing, security audit, vulnerability assessment, and penetration testing roadmap.
CEH6	System Hacking	System hacking methodology, steganography, steganalysis attacks, and covering tracks.
CEH7	Malware Threats	Different types of Trojans, Trojan analysis, and Trojan countermeasures. Working of viruses, virus analysis, computer worms, malware analysis procedure, and countermeasures.
CEH8	Sniffing	Packet sniffing techniques and how to defend against sniffing.
CEH9	Social Engineering	Social Engineering techniques, identify theft, and social engineering countermeasures.
CEH10	Denial-of-Service	DoS/DDoS attack techniques, botnets, DDoS attack tools, and DoS/DDoS countermeasures.
CEH11	Session Hijacking	Session hijacking techniques and countermeasures.
CEH12	Evading IDS, Firewalls, and Honeypots	Firewall, IDS and honeypot evasion techniques, evasion tools, and countermeasures.
CEH13	Hacking Web Servers	Different types of webserver attacks, attack methodology, and countermeasures.
CEH14	Hacking Web Applications	Different types of web application attacks, web application hacking methodology, and countermeasures.
CEH15	SQL Injection	SQL injection attacks and injection detection tools.

CEH16	Hacking Wireless Networks	Wireless Encryption, wireless hacking methodology, wireless hacking tools, and Wi-Fi security tools.
CEH17	Hacking Mobile Platforms	Mobile platform attack vector, android vulnerabilities, mobile security guidelines, and tools.
CEH18	IoT Hacking	Different threats to IoT platforms and learn how to defend IoT devices securely.
CEH19	Cloud Computing	Various cloud computing concepts, threats, attacks, and security techniques and tools.
CEH20	Cryptography	Different types of cryptography ciphers, Public Key Infrastructure (PKI), cryptography attacks, and cryptanalysis tools.

The section below describes how learning materials of CEH v10, supported by the EC-council, has been designed and fed in the SMART Learning Environment. A pool of questions was established following the CEH Curriculum shown in the table above and also bearing in mind the pedagogical and instructional models of ADDIE and Bloom's Taxonomy described above.

Sample Multiple Choice Questions

The questions set were mostly in the form of Multiple-Choice Questions (MCQ) and some examples are given below. The MCQs serve mostly as assessment of the competencies and knowledge gathered by the learner throughout the learning process. One important aspect of this exercise is the proper tagging of questions, firstly, tagging a particular question according to the topic it covers and secondly according to its level of difficulty. Tagging of a particular question according to the chapter covered is done through the use of the Chapter ID, eg CEH 12 (for Chapter 'Evading IDS, Firewalls, and Honeypots') and the level of the question is determined by the use of Bloom's Taxonomy. The idea again as mentioned is to ensure that the learners reach a higher cognitive level instead of passively recalling information. The use of specific words to formulate the question is also important. For example, a question using 'define' or 'describe' is simply asking the learner to memorise or recall and is therefore at level 1 and has been assigned a weight of 1. The questions have been split into 6 levels and the weights assigned are shown in Figure 4.8.

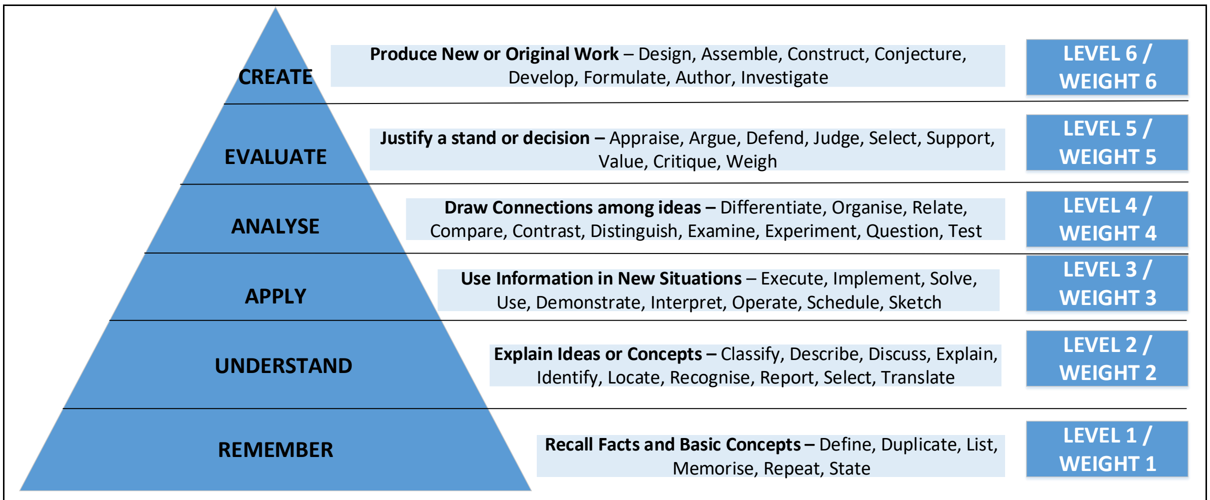
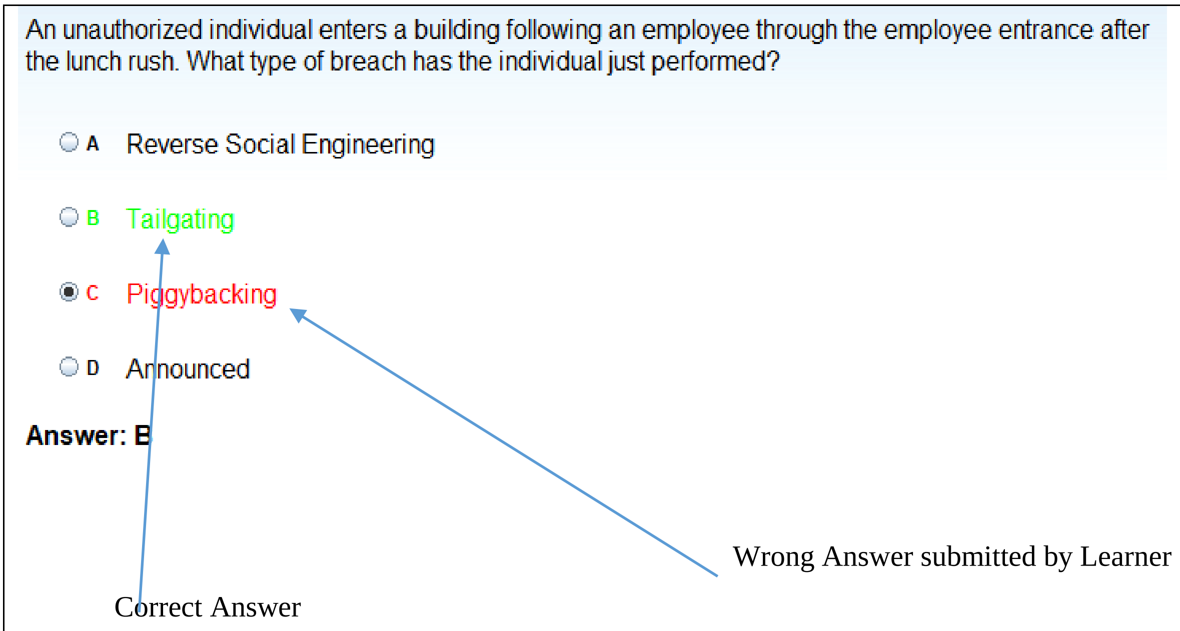


Figure 4. 8: Bloom's Taxonomy used to identify level of difficulty of questions

(Source: Researcher's own construction)



The above question has been tagged as covering Chapter CEH 9 (Social Engineering) and having a difficulty level of 1 since as per Bloom's Taxonomy, the learner is expected to only recall the type of breach, that is, 'REMEMBER'. The answer submitted by the learner is compared to the correct answer stored in the database and the MCQ marked accordingly so as to get the score of the learner

Figure 4. 9: Sample MCQ

(Source: Adapted from Pass4Sure, 2019)

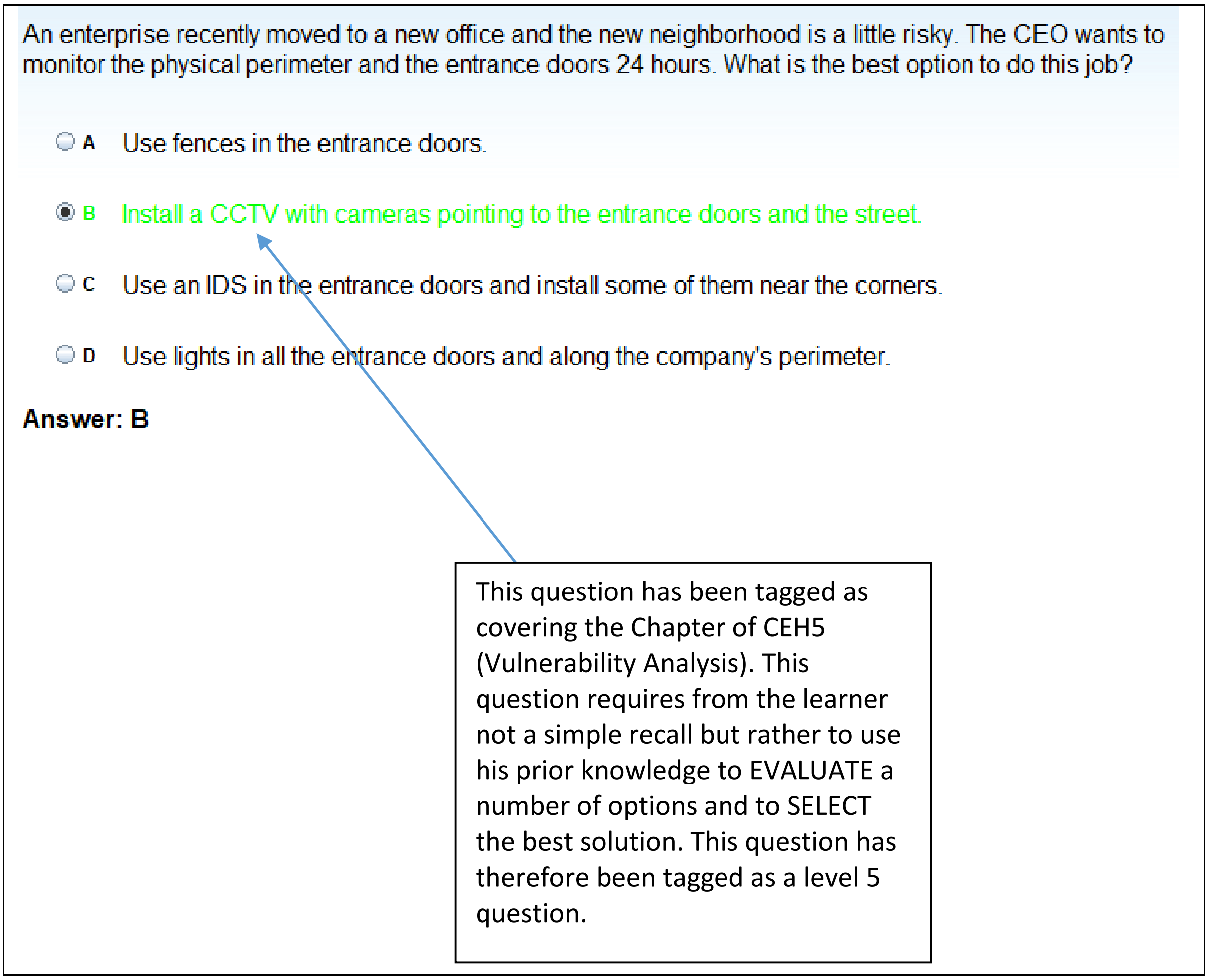


Figure 4. 10: Sample MCQ with explanation

(Source: Adapted from Pass4Sure, 2019)

Learning Materials

Learning materials to be used on the SMART Learning Environment serves mainly two purposes. The first one is to bring required knowledge and skills to the learner prior to the assessment exercises. The assessment is done mostly through the use of post-tests. The second purpose of the learning materials is to serve as reinforcement materials for the learner where certain weaknesses and training gaps are observed. The learning materials have been designed bearing in mind the different learning styles of learners, namely Visual, Auditory and Kinesthetic (VAK). It is understood that most learners have a predominantly preferred learning style but however, most learners are able to use a blend of the different learning styles. Learning materials have been designed in the form of Web-based materials for to cover the Visual aspect, video lectures for Auditory purposes and some simulation and experimentation for Kinesthetic. The researcher has used a blend of these three forms to make the learning process more interesting and to stimulate learners by showing to them materials in the format they are interested in. It is also important to point out that the learning materials are not statically loaded on the Web interface but rather stored in the database for better maintenance. Here, again tagging of the learning materials, is imperative for their future retrieval.

Micro Learning

The educational content has been designed in such a way that micro learning is preferred. Micro learning encourages the learner to tackle the learning process using a divide and conquer approach, whereby the learner learns in steps with some well-defined learning activities, chunks or units instead of asking the learner to spend hours learning a particular topic. This approach enables the learning process to be more effective bearing in mind the learner's cognitive constraints. Indeed the learner's attention span is limited and using micro-learning, the learning process is more targeted and fruitful.

Development Tools and Environment Used

The table below summarises the development tools and environment used.

Table 4.3: Development Tools and Environment

	Development Tools and Environment
1	NetBeans is an integrated development environment which comprises of a full featured debugger. It mainly uses Java programming language which will help to implement the different functionalities and features needed in the system. Also, it allows the usage of Neural Studio.
2	phpMyAdmin is a freely available and open source tool written in PHP and is meant to handle the administration of MySQL with the use of a web browser. It can perform various tasks such as the creation, modification or deletion of databases, tables, fields or rows, using SQL statements.
3	Neuroph Studio is a lightweight Java neural network framework to develop common neural network architectures. It contains well-designed, open source Java library.
4	Miro which is a lightweight open source video / podcast manager which provide robust features of multimedia and streaming.

Database and Database Design

The Database provides an organised way of keeping data which can thereafter be used and analysed to provide personalised learning materials and appropriate feedback. The database acts as a centralised repository of data, which will be used by all the modules of the SMART Learning Environment. Information pertaining to the design of the database is presented in Table 4.4.

Table 4.4: User Table

(Source: Researcher's own construction)

Variable Name	Data Type	Description
Username	String	Unique identifier to avoid duplication of the same username during registration.
Email	String	The Email Address of the user.
First_Name	String	The first name of the user.
Last_Name	String	The last name of the user.
Password	String	Password of the user for accessing the application.
DOB	Date/Time	Date of birth of the user.
Current_Chapter	Integer	Current value of chapter reached.
Current_Level	Integer	Current value of level being learnt.
Last_Login_Date	Date/Time	Date when the user last accessed the application.
Last_Login_Time	Timestamp	Time when the user last accessed the application.
Level1_Category	String	Category of student after post-test1.

Level1_Duration	Timestamp	Duration to complete post-test1, in seconds.
Level1_Marks	Integer	Marks of level 1.
Level2_Category	String	Category of student after post-test2.
Level2_Duration	Timestamp	Duration to complete post-test2, in seconds.
Level2_Marks	Integer	Marks of level 2.
Level3_Category	String	Category of student after post-test3.
Level3_Duration	Timestamp	Duration to complete post-test3, in seconds.
Level3_Marks	Integer	Marks of level 3.
Level4_Category	String	Category of student after post-test4.
Level4_Duration	Timestamp	Duration to complete post-test4, in seconds.
Level4_Marks	Integer	Marks of level 4.
Level5_Category	String	Category of student after post-test5.
Level5_Duration	Timestamp	Duration to complete post-test5, in seconds.
Level5_Marks	Integer	Marks of level 5.
Level6_Category	String	Category of student after post-test6.
Level6_Duration	Timestamp	Duration to complete post-test6, in seconds.
Level6_Marks	Integer	Marks of level 6
PreTest_Category	String	Category of student after pre-test.
PreTest_Duration	Timestamp	Time taken by user to perform the pre-test.

PreTest_Marks	Integer	Marks of pre-test.
Registered_Date	Date/Time	Date when the user registered onto the application.
Registered_Time	Timestamp	Specific time saved when user was registering.

Table 4.5: Chapter Table

(Source: Researcher's own construction)

Variable Name	**Data Type**	**Description**
Chapter	String	Unique Identifier of chapters.
Question Number (*) KEY	Integer	Question number in different chapters.
A	String	MCQ answer of option A.
B	String	MCQ answer of option B.
C	String	MCQ answer of option C.
D	String	MCQ answer of option D.
Answer	String	Answer of the question.
Question	String	Question of the chapter.
Solution	String	Correct answer.

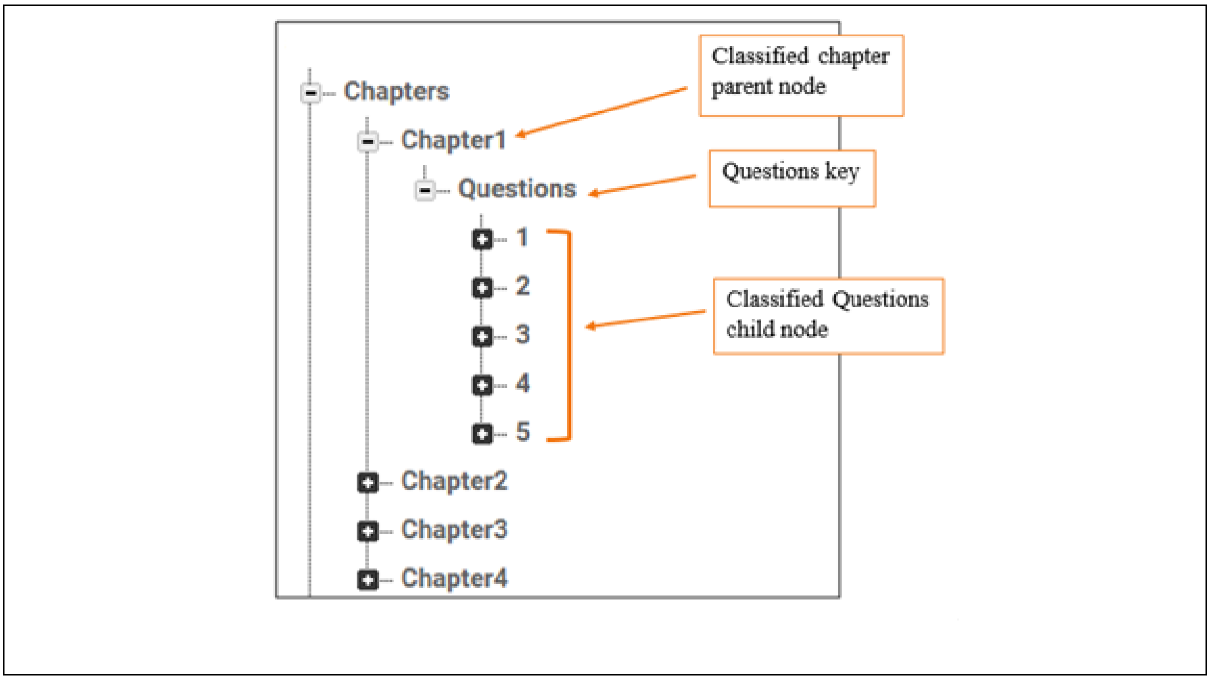


Figure 4. 11: Chapter hierarchy

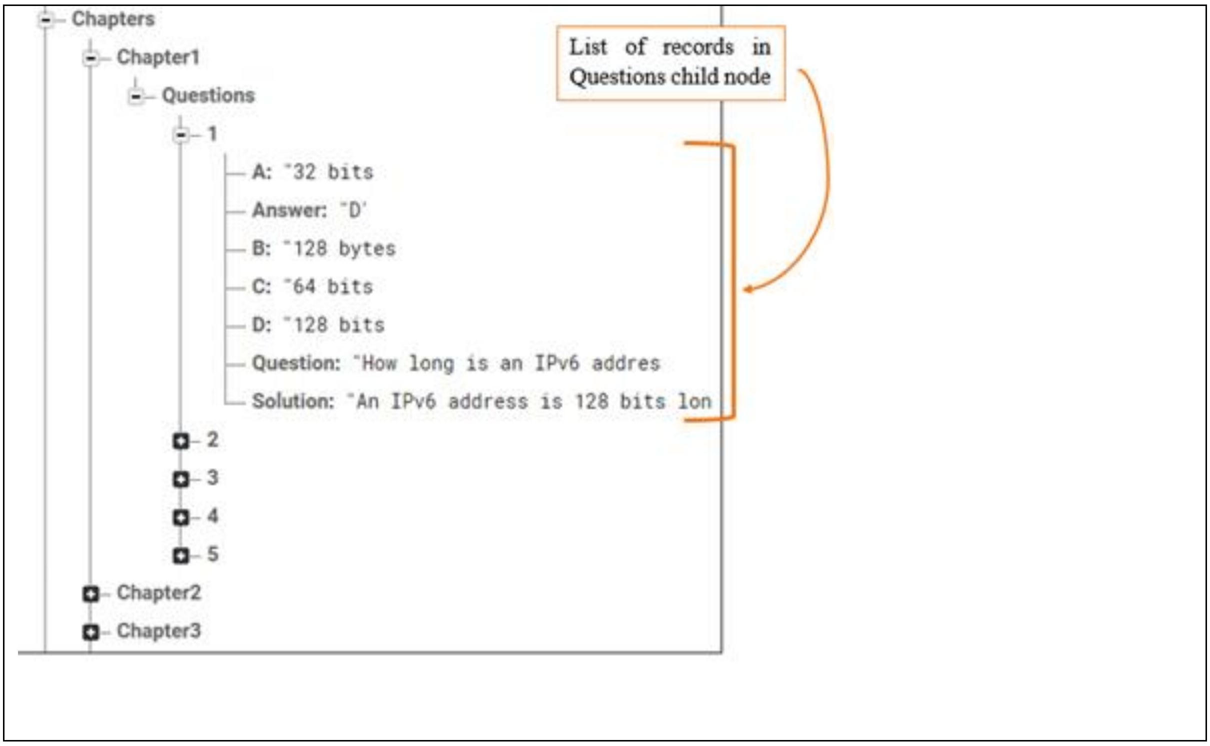


Figure 4. 12: Database view of question and answers

Table 4.6: PreTest

(Source: Researcher's own construction)

Variable Name	Data Type	Description
Question_Number	Integer	Unique identifier of question numbers.
AnsA	String	MCQ answer of option A.
AnsB	String	MCQ answer of option B.
AnsC	String	MCQ answer of option C.
AnsD	String	MCQ answer of option D.
CorrectAnswer	String	MCQ answer correct option stored.
Question	String	Question of the MCQ answers.

Table 4.7: PostTest

(Source: Researcher's own construction)

Variable Name	Data Type	Description
Question_Number	Integer	Unique identifier of question numbers.
AnsA	String	MCQ answer of option A.
AnsB	String	MCQ answer of option B.
AnsC	String	MCQ answer of option C.
AnsD	String	MCQ answer of option D.

CorrectAnswer	String	MCQ answer correct option stored.
Question	String	Question of the MCQ answers.

Table 4.8: Unanswered_Questions

(Source: Researcher's own construction)

Variable Name	**Data Type**	**Description**
Username	String	Unique identifier for each user.
Test	String	Specifies pre-test or post-test.
Question Number	Integer	Unique identifier of question numbers.

2) An Initial Competency Level Determination Module.

This module will help determine the prior knowledge of the learner. Determining the prior knowledge of the learner can be a subtle process and according to the researcher, there might be three possible ways of determining the prior knowledge of the learner.

Option 1: Self-Evaluation

This option is quick and easy but the problem lies that in the fact that the learner might underestimate or overestimate his prior knowledge. Asking the learner to rate himself or herself might be very much of a subjective process.

Option 2: Pre-Testing

Using an MCQ test, the learner can be classified as *poor*, *average* or *expert* depending on the percentage of questions answered well. However, this method, neglects the level of confidence of the learner in answering a particular question.

Option3: Use of the Rasch Model and Expectation

There can be a number of ways to measure the performance of a learner but one interesting means of doing so is through the Item Response Theory (IRT). The Item Response Theory (also known as modern mental test theory), is a theory based on the relationship between individuals' performance on a test item and the test takers' levels of performance on an general measure of the ability that item was intended to amount (Carlson and Davier, 2017). For the purpose of this research, a simple model known as the Rasch Model or 1PL Model will be discussed. This well-known psychometric model uses item difficulty as a parameter for computing a person's capability. It relates performance to student ability (treated here as overall knowledge of the domain) and item difficulty (Ma et al., 2016). The equation below shows the equation for 1PL model (Baker, 2001).

$$P(\Theta) = \frac{1}{1 + e^{-1(\theta - b)}}$$

Where b is the question difficulty parameter, θ is the student ability (knowledge) level, and P(θ) is the probability that the student will answer the current item correctly. Within this model, if a student's ability is equal to the item's difficulty (θ = b), the probability that the student will answer the question correctly is 50%. As the student's ability becomes higher or the item's difficulty becomes lower, the probability of correctness increases and finally is approximately equal to 1; correspondingly, as ability becomes lower or difficulty becomes higher, the probability of correctness approaches 0 (Ma et al.,2016).

$$E(X) = \sum_{i=1}^{n} x_i \,.\, P_i$$

X = random variable for marks for n questions

n = number of questions

P_i = probability question i is correct

X = marks for question i

Figure 4. 13: Expectation

(Source: Researcher's own construction)

Pseudocode for measuring learner's prior knowledge is shown below:

Step 1: Use the IRT formulae below to get probability a learner correctly answers a question

$$P(\Theta) = \frac{1}{1 + e^{-1(\theta - b)}}$$

Where

P(Θ) = Probability the learner answers the question correctly

b = question difficulty parameter

Θ = student knowledge (K(L))

K(L) = Marks for a particular question x Confidence Level of student

To monitor the user confidence during a pre-test, two parameters were monitored

1. Time taken to answer a question
2. Number of times the answer was changed

Step 2: The following formula was used to get the expected result of user for the pre-test

$E(Result) = \sum P(\Theta)$. Weight of question

A list of 20 questions was used for the pre-test

Real result obtained by the user during the pre-test was calculated as follows:

$$Real\ (Result) = \frac{marksobtained}{totalmarks}$$

Step 3: Progress of the performance of the learner was calculated as follows:

$$Rise\ or\ Drop\ in\ performance = Real\ (Result) - Expected\ (Result)$$

If time taken to answer question was less than 10 seconds, user confidence will be 0.75 which is high confidence value.

Figure 4. 14: Item Response Theory

(Source: Researcher's own construction)

For the purpose of this research and after the Expert Reference Group Discussion carried out, the pre-test method through the use of MCQ was chosen and implemented as the means to collect the prior knowledge of the learner. This involves asking the learner a series of questions and then comparing the answers to correct answers stored in the database. One of the limitations of this method is that it does not take into account the confidence level of the learner in answering the questions. To counterbalance this, another parameter was used, that is, time taken to answer the test. Therefore two outputs from the pre-test, namely Test Score and Time Taken are recorded. These would then be used as inputs for the Personalised Learning Module. Fill-in-blanks and Open-Ended questions are possible but it will involve the use of other techniques such as Deep Learning.

3) A Learning Performance Evaluation Module.

This module evaluates the learner's performance through the use of online tests and other learning activities. Again the same principle of comparing the answers of the learner to a correct one stored in the database is used. Details about the specific learner is kept and can eventually be used to provide personalised learning materials based on his/her performance. This module is different from the Initial Competency Level Determination Module which was basically used to capture the prior knowledge of the learner. The Learning Performance Evaluation Module will track the progress of the learner from the very beginning and ensure that the learner reaches to the desired level.

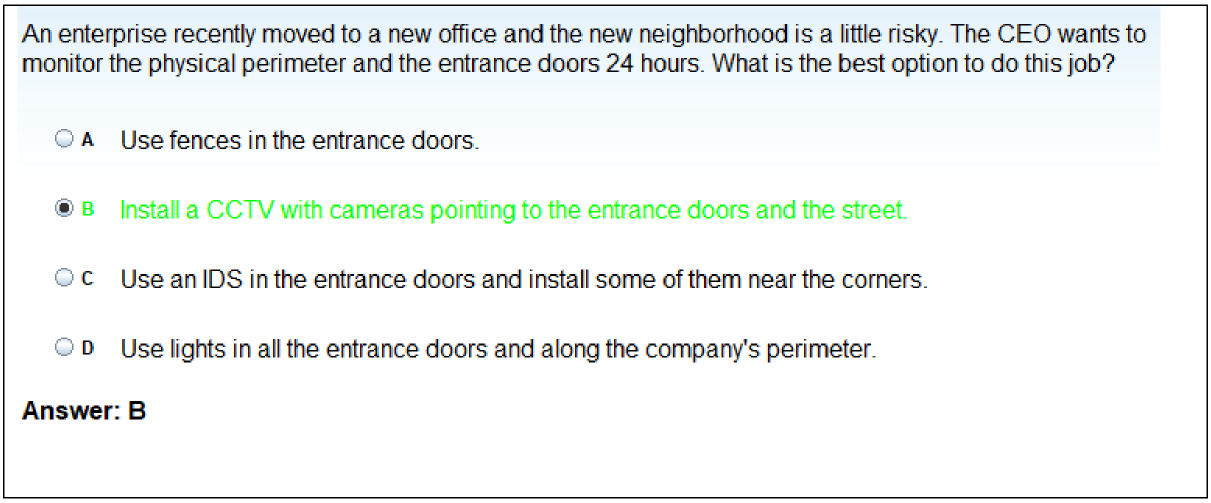


Figure 4. 15: Sample activities in Learning Performance Evaluation Module

4) **A Personalised Learning Module.**

This module adapts the learning contents, materials and tasks based on the learner's prior knowledge, performance and learning objectives. Personalisation and adaptation has been recognised as being a key concept for effective and efficient learning to take place. This has been supported by previous research carried out by a number of scholars as summarised in Chapter 2.

A data mining approach was used to construct the SMART Learning Environment, more specifically, a four-step approach on an artificial neural network (ANN) core data mining technique. Moreover, a back- propagation (BP) algorithm selected from the ANNs will be used for the supervised cluster classification of student learning performances namely; the Test Score obtained from the Initial Competency Level Determination (Pre-test) and the Time Taken to complete the test.

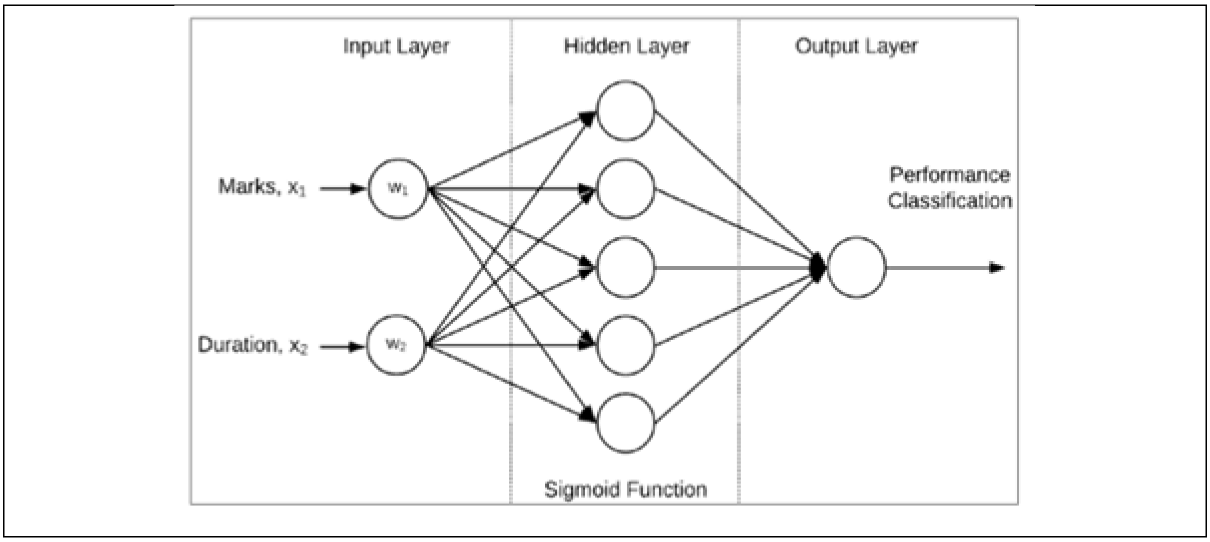


Figure 4. 16: Artificial Neural Network

ANNs are comprised of processing elements, that is, nodes and neurons and their connections. The nodes are connected layer-wise among themselves. The neural network consists of 3 layers namely: input layer, hidden layer and output layer as shown below and discussed in Chapter 2.

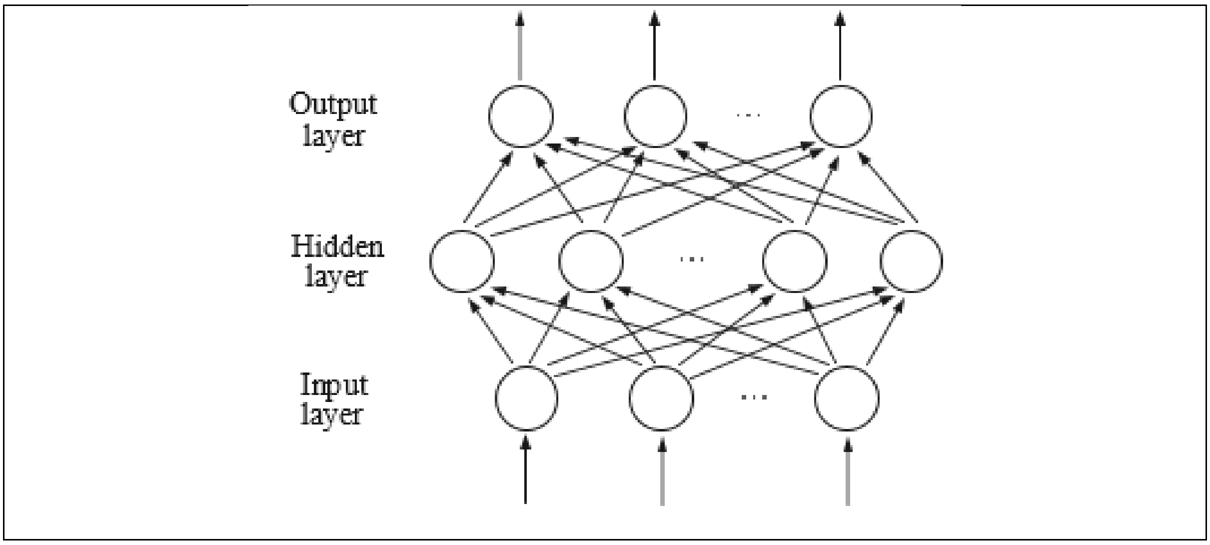


Figure 4. 17: Artificial Neural Network

(Source: Researcher's own construction)

After choosing the weights of the network randomly, the Backpropagation algorithm is used to compute the necessary corrections. The algorithm can be broken down in the following four steps:

- Feed-forward computation
- Backpropagation to the output layer
- Backpropagation to the hidden layer
- Weight updates

The algorithm stops when the value of the error function becomes sufficiently small. In addition to this, a training set of data has been implemented so that the neural network can be trained. Moreover, the flowchart of how to train the network is illustrated below.

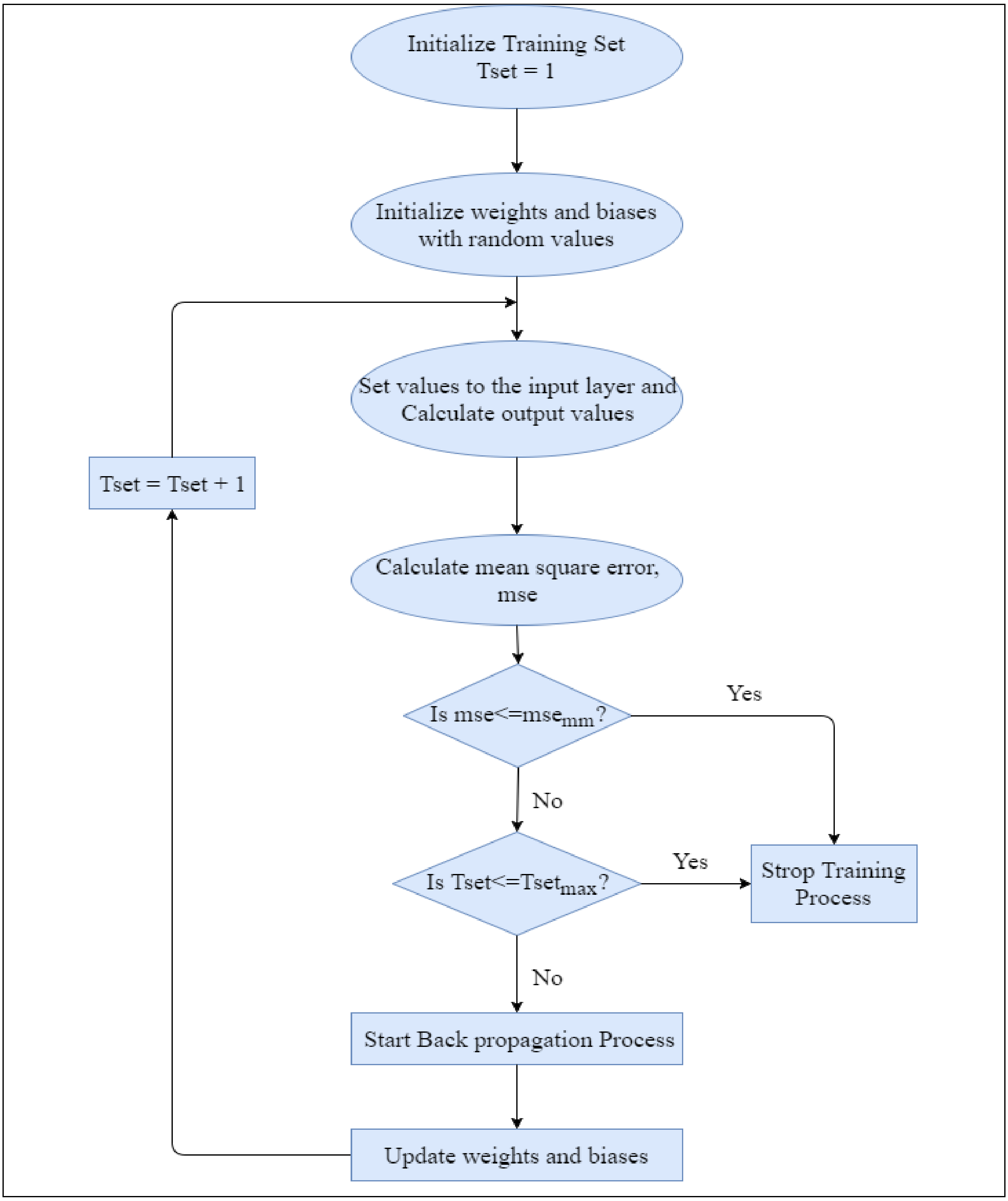


Figure 4. 18: Artificial Neural Network Training Flowchart

(Source: Researcher's own construction)

After the Artificial Neural Network has been trained, the SMART Learning Environment is able to generate the personalised learning pathway for the learners. The Personalised Learning Module consists of 6 levels of Learning Materials, Level 1 to 6, each level increasing in the complexity of the learning material. After a learner has completed the materials for a particular level, he/she is subjected to a post-test for that particular level. Again, the parameters of the test score and the time taken to complete the test will be considered. If the learner clears the test, the learner is promoted to the next level. In case the learner fails the post-test, the learner will be made to learn the same learning materials again.

Also, the pseudocode for the Backpropagation Algorithm is shown below.

```
initialize network weights (often small random values)
 do
   for each training example named β
     prediction = neural-net-output (network, β) // forward pass
     actual = α-output (β)
     compute error (prediction - actual) at the output units
     compute wi for all weights from hidden layer to output layer // backward pass
     compute wj  for all weights from input layer to hidden layer // backward pass continued
     update network weights // input layer not modified by error estimate
 until all examples classified correctly or another stopping criterion satisfied
 return the network
```

Figure 4. 19: Pseudocode for BackPropagation Algorithm

(Source: Adapted from Chattopadhyay and Bandyopadhyay, 2007)

A second algorithm was derived, namely the Average Weighted Performance Algorithm. Its main functionality is to check whether a student is eligible to go through the same learning content again if he fails a post-test or if the system needs to backtrack him to the previous level. The Average Weighted Performance was used to give each learner a fair judgment in case he/she fails to clear a test. The weights of the 6 post-tests are given below. The general formula of the Average Weighted Performance is shown below.

$$Average\ Weighted\ Performance = \frac{\sum_{i=1}^{6}(Score_i * Weight_i)}{\sum_{i=1}^{6} Weight_i}$$

Figure 4. 20: Formula for Average Weighted Performance

(Source: Researcher's own construction)

The flowchart for computing the Average Weighted Performance is shown below.

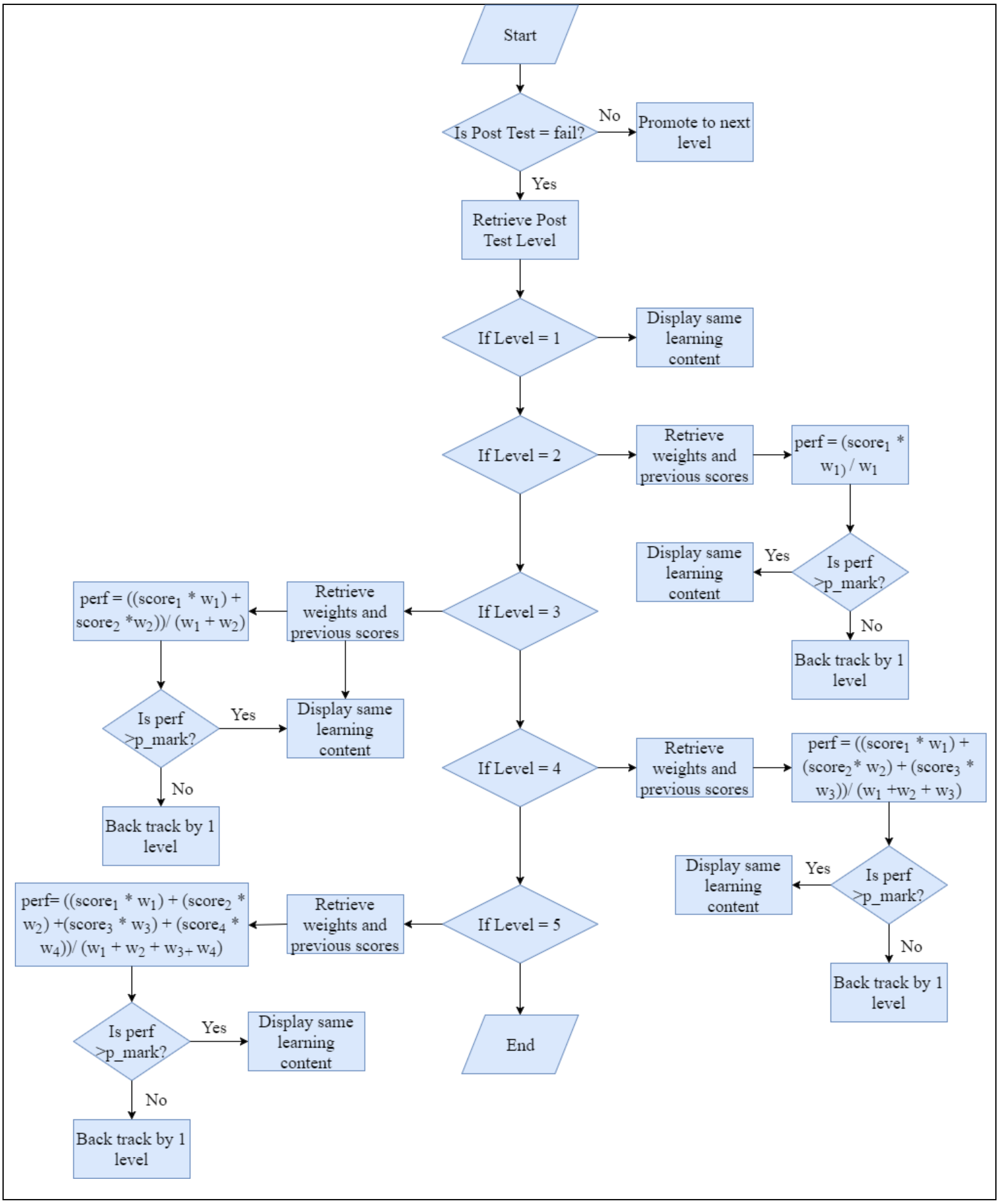


Figure 4. 21: Average Weighted Performance Flowchart for a level 5 test

(Source: Researcher's own construction)

In terms of pseudocode, the Average Weighted Performance mechanism is shown below.

```
if post_test = fail THEN
                Retrieve the level of the post test
if post_test_level = 1 THEN
                display the same learning content
if post_test_level = 2 THEN
                retrieve score of previous tests
                performance = (score1 * w1) / w1
        if performance > p_mark THEN
                display the same learning content
      ELSE backtrack to previous level
ELSE IF post_test_level = 3 THEN
                retrieve score of previous tests
                performance = ((score1 * w1) + score2 * w2)) / (w1 + w2)
         if performance > p_mark THEN
                display the same learning content
       ELSE backtrack to previous level
ELSE IF post_test_level = 4 THEN
                retrieve score of previous tests
               performance = ((score1 * w1) + (score2 * w2) + (score3 * w3)) / (w1 + w2 + w3)
          if performance > p_mark THEN
                display the same learning content
        ELSE backtrack to previous level
ELSE IF post_test_level = 5 THEN
                retrieve score of previous tests
               performance = ((score1 * w1) + (score2 * w2) + (score3 * w3) + (score4 * w4)) / (w1
+ w2 + w3 + w4)
        if performance > p_mark THEN
                display the same learning content
      ELSE backtrack to previous level
ELSE IF post_test_level = 6 THEN
                retrieve score of previous tests
               performance = ((score1 * w1) + (score2 * w2) + (score3 * w3) + (score4 * w4) + (score5
* w5)) / (w1 + w2 + w3 + w4 + w5)
        if performance > p_mark THEN
                display the same learning content
```

```
        ELSE backtrack to previous level

END IF
   END IF
      END IF
         END IF
```

Figure 4. 22: Pseudocode for Average Weighted Performance

(Source: Researcher's own construction)

For the purpose of this research, the Artificial Neural Network has been implemented using Neuroph Studio coupled with NetBeans. This can further be expanded as shown below

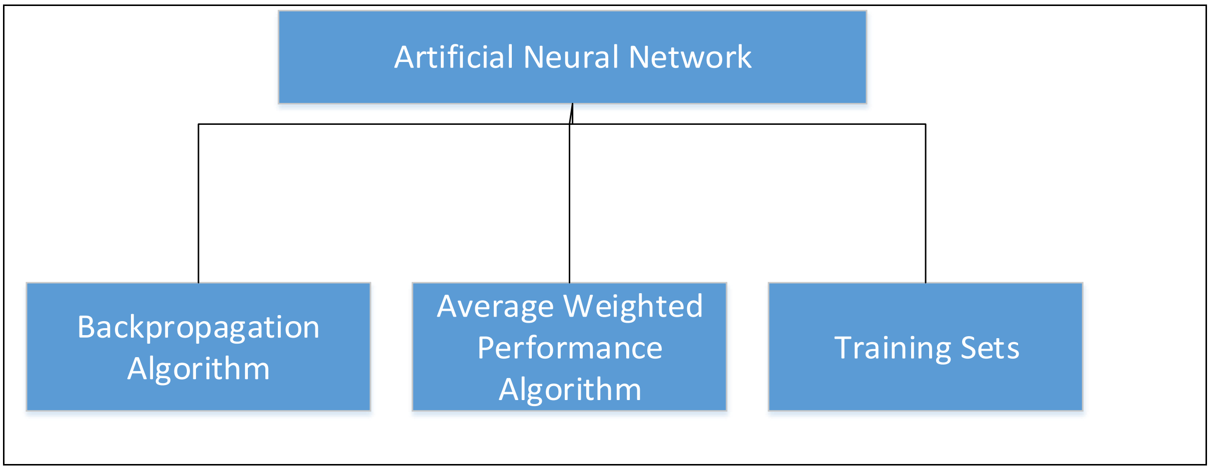


Figure 4. 23: Expansion of Artificial Neural Network

(Source: Researcher's own construction)

Creating Neural Network on Neuroph Studio

To implement the SMART Learning Environment, a Multi-Layer perceptron which is a type of neural network that can be used in prediction and recognition has been used. This is very often used in situations where problems are not linearly separable. It is a feed forward neural network with a single or multiple layers separating the input and the output layer. The Multi-Layer Perceptron is trained with the Backpropagation Learning algorithm which has been explained above. The steps to create and train the neural network are explained below.

Step 1: Create New Project on Neuroph Studio.

Step 2: Create Neural Network and choose Multi-Layer Perceptron.

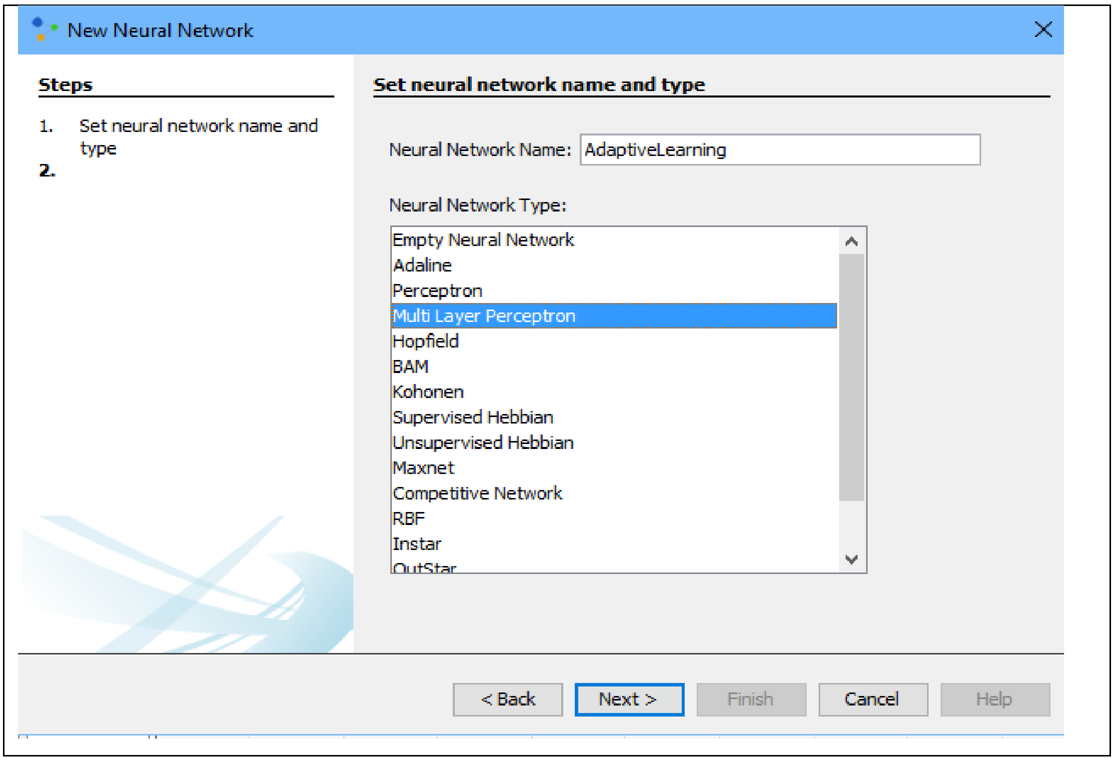


Figure 4. 24: Creation of Neural Network – part 1

Step 3: Enter number of Input, Hidden and Output Neuron. Select the Sigmoid Transfer Function and select Backpropagation for Learning rule.

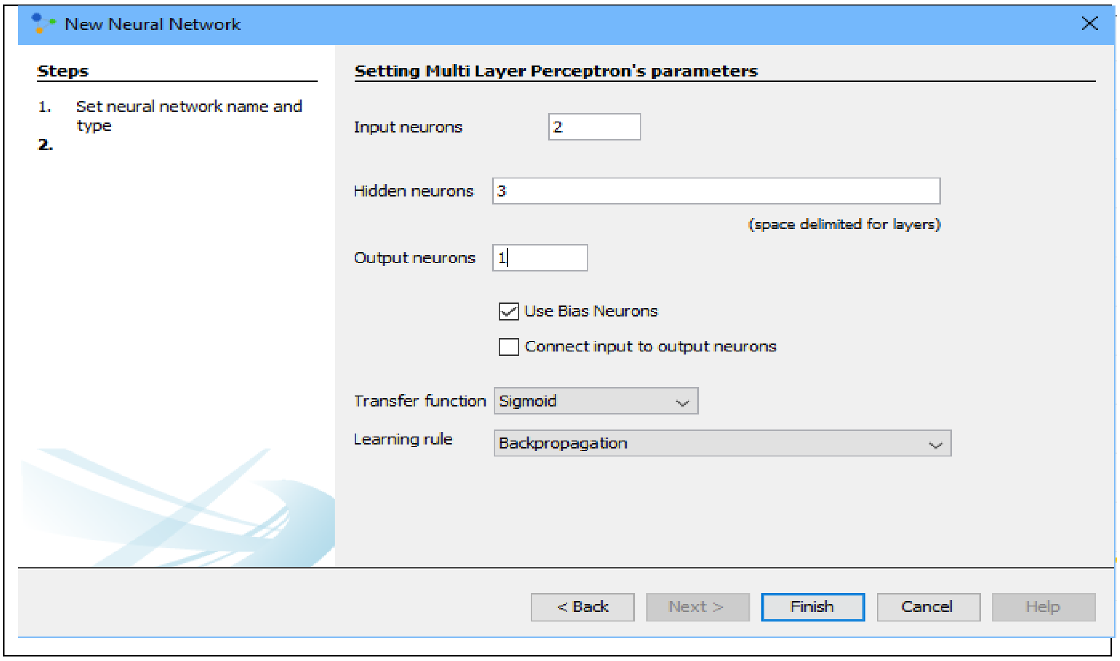


Figure 4. 25: Creation of Neural Network – part 2

This will create the Neural Network with the number of the different neurons which has been input.

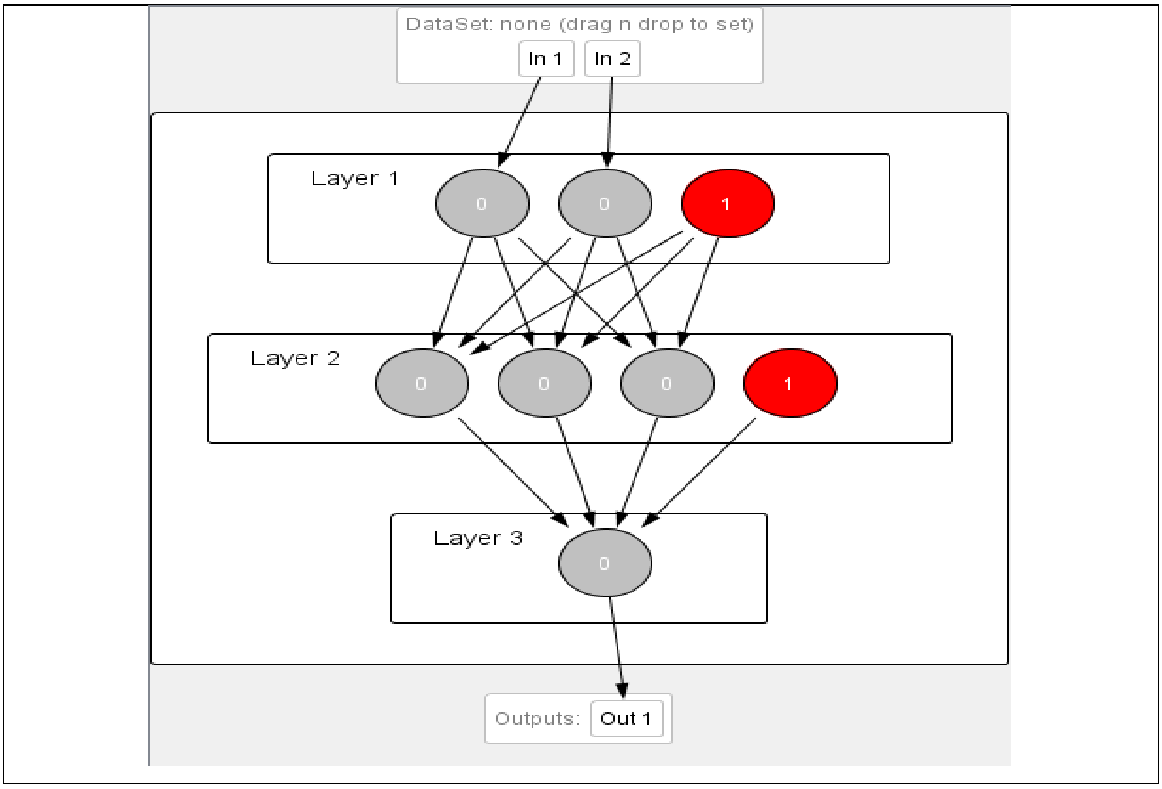


Figure 4. 26: Creation of Neural Network – part 3

Step 4: Create the dataset which will be used to train our neural network.

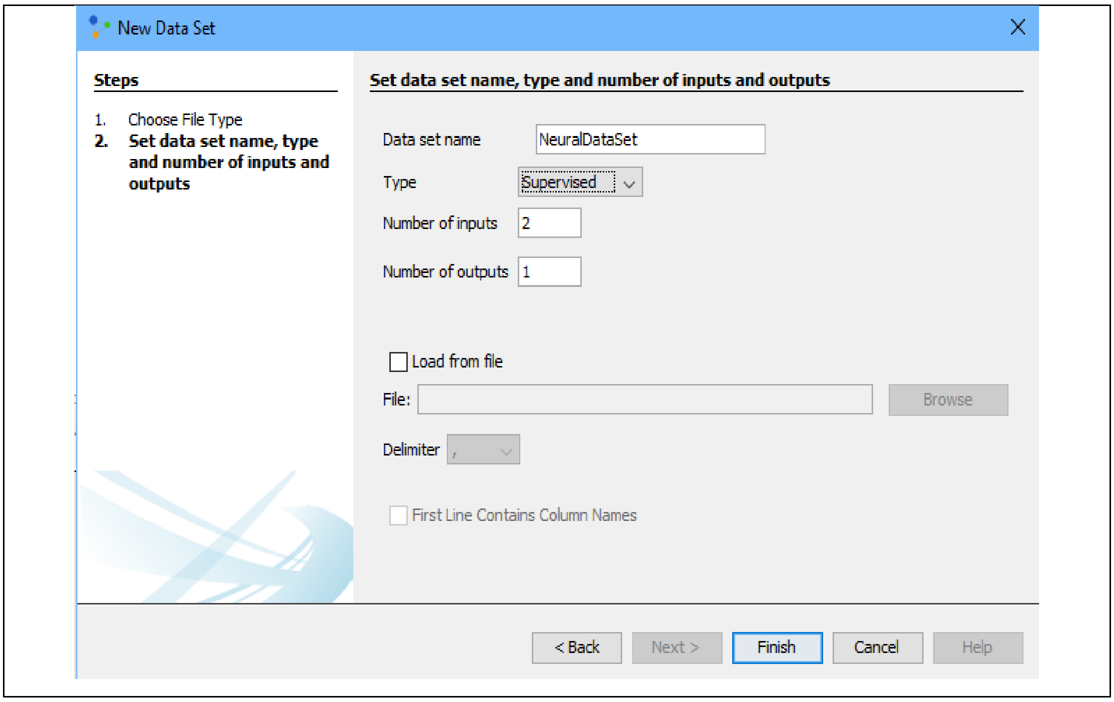


Figure 4. 27: Creation of Neural Network – part 4

Step 5: Before inserting the training elements in the training sets, normalization is performed by scaling each value between 0 and 1. The formulae below has been used to perform this operation.

$$Normalized\ (e_i) = \frac{e_i - E_{min}}{E_{max} - E_{min}}$$

where

E_{min} = the minimum value for variable E

E_{max} = the maximum value for variable E

Figure 4. 28: Normalization

Step 6: After normalising each value, the training set is created by entering the training elements with the input neurons and their output neurons respectively. To train the neural network, 50 training sets have been used. This is shown in Figure 4.29.

Input 1	Input 2	Output 1
0.1	0.2	0.0
0.2	0.2	0.0
0.3	0.2	0.0
0.4	0.2	0.0
0.5	0.2	0.0
0.6	0.2	0.0
0.7	0.2	1.0
0.8	0.2	1.0
0.9	0.2	1.0
1.0	0.2	1.0
0.1	0.4	0.0
0.2	0.4	0.0
0.3	0.4	0.0
0.4	0.4	0.0
0.5	0.4	0.0
0.6	0.4	0.0
0.7	0.4	1.0
0.8	0.4	1.0
0.9	0.4	1.0
1.0	0.4	1.0
0.1	0.6	0.0
0.2	0.6	0.0
0.3	0.6	0.0
0.4	0.6	0.0
0.5	0.6	0.0
0.6	0.6	0.0
0.7	0.6	1.0
0.8	0.6	1.0
0.9	0.6	1.0
1.0	0.6	1.0
0.1	0.8	0.0
0.2	0.8	0.0
0.3	0.8	0.0
0.4	0.8	0.0
0.5	0.8	0.0
0.6	0.8	0.0
0.7	0.8	1.0
0.8	0.8	1.0
0.9	0.8	1.0
1.0	0.8	1.0
0.1	1.0	0.0
0.2	1.0	0.0
0.3	1.0	0.0
0.4	1.0	0.0
0.5	1.0	0.0
0.6	1.0	0.0
0.7	1.0	0.0
0.8	1.0	0.0
0.9	1.0	0.0
1.0	1.0	0.0

Figure 4. 29: Training Sets

Step 7: Training the network with the training sets and specifying the learning rate and momentum.

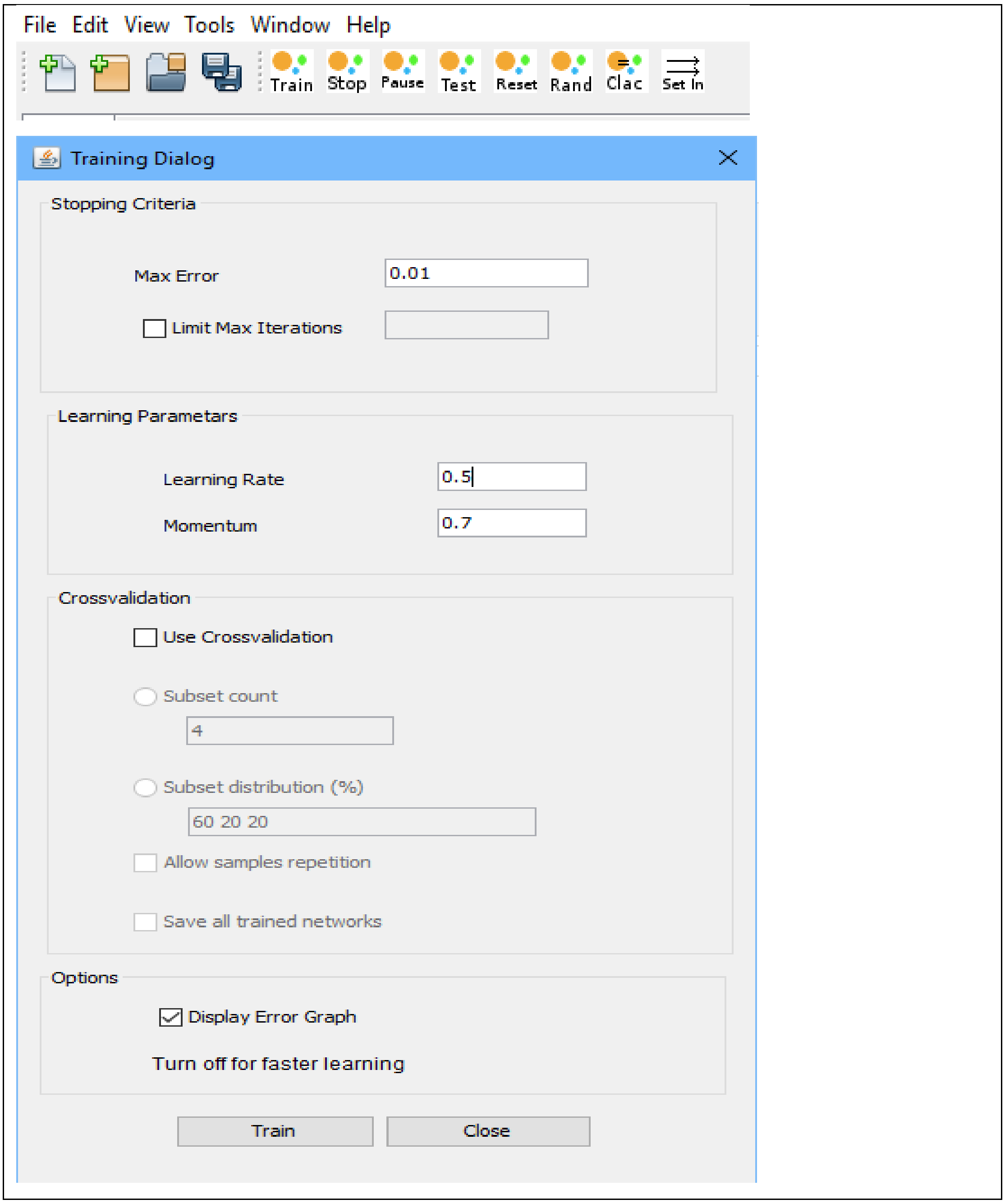


Figure 4. 30: Training the Artificial Neural Network

Figure 4.31 below demonstrates that the training stops after 1500 iterations with total error under 0.01.

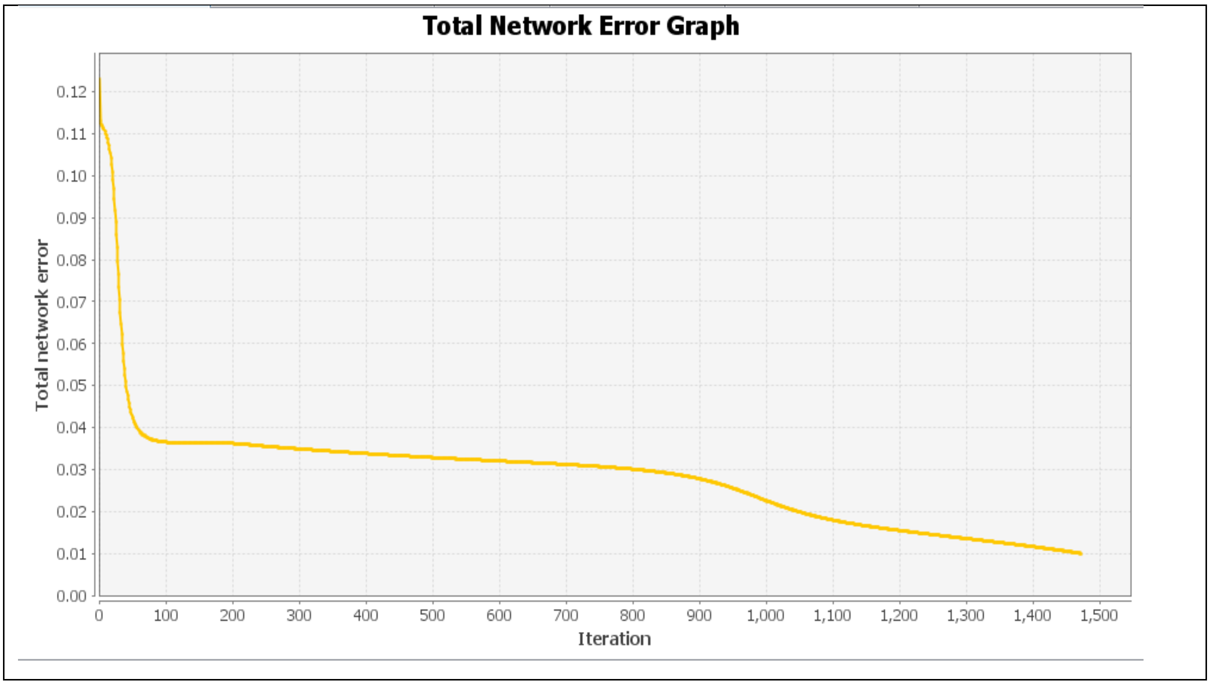


Figure 4. 31: Total Network Error Graph 1

After adjusting the learning rate of the training, the results can be observed below.
The training stopped after just 210 iterations with total error under 0.01.

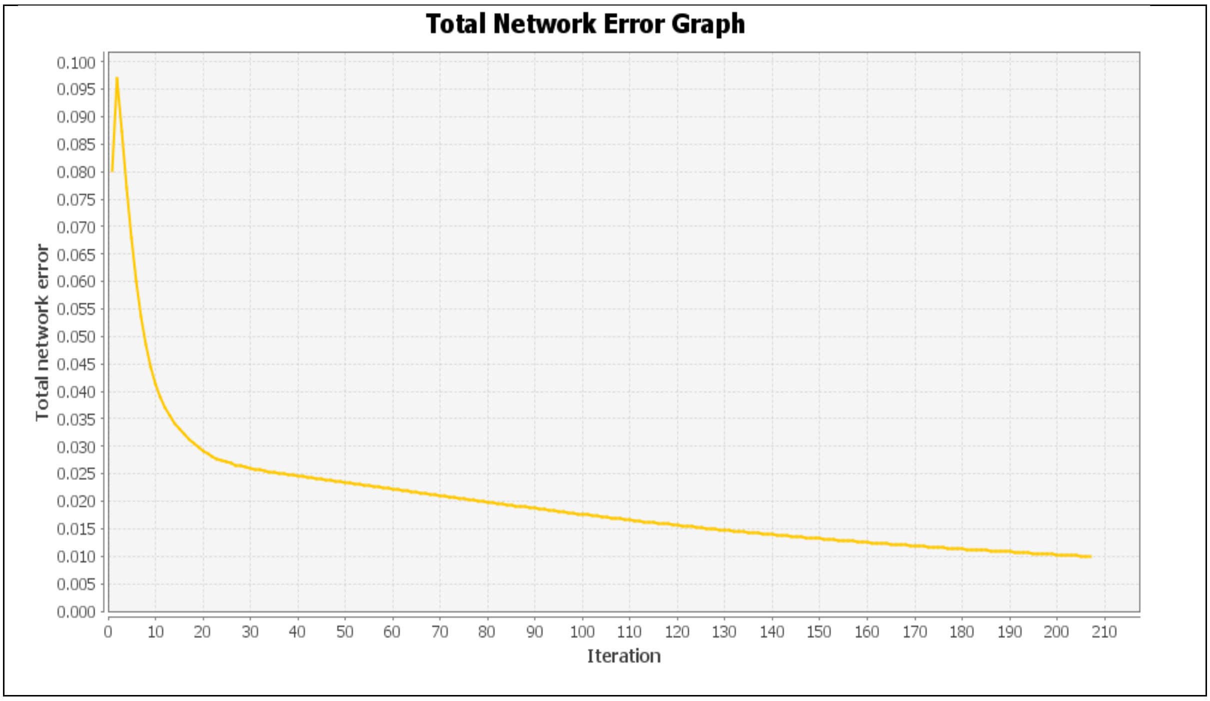


Figure 4. 32: Total Network Error Graph 2

Step 8: Testing the trained network. The figures below display the results when the network has been tested and showing Total Mean Square Error: 0.01.

```
Input: 0.1; 0.2;  Output: 0.001; Desired output: 0;  Error: 0.001;
Input: 0.2; 0.2;  Output: 0.001; Desired output: 0;  Error: 0.001;
Input: 0.3; 0.2;  Output: 0.0013; Desired output: 0;  Error: 0.0013;
Input: 0.4; 0.2;  Output: 0.0022; Desired output: 0;  Error: 0.0022;
Input: 0.5; 0.2;  Output: 0.0086; Desired output: 0;  Error: 0.0086;
Input: 0.6; 0.2;  Output: 0.1387; Desired output: 0;  Error: 0.1387;
Input: 0.7; 0.2;  Output: 0.9495; Desired output: 1;  Error: -0.0505;
Input: 0.8; 0.2;  Output: 0.9997; Desired output: 1;  Error: -0.0003;
Input: 0.9; 0.2;  Output: 1; Desired output: 1;  Error: -0;
Input: 1; 0.2;  Output: 1; Desired output: 1;  Error: -0;
Input: 0.1; 0.4;  Output: 0.0006; Desired output: 0;  Error: 0.0006;
Input: 0.2; 0.4;  Output: 0.0008; Desired output: 0;  Error: 0.0008;
Input: 0.3; 0.4;  Output: 0.0012; Desired output: 0;  Error: 0.0012;
Input: 0.4; 0.4;  Output: 0.0024; Desired output: 0;  Error: 0.0024;
Input: 0.5; 0.4;  Output: 0.0104; Desired output: 0;  Error: 0.0104;
Input: 0.6; 0.4;  Output: 0.1294; Desired output: 0;  Error: 0.1294;
Input: 0.7; 0.4;  Output: 0.8154; Desired output: 1;  Error: -0.1846;
Input: 0.8; 0.4;  Output: 0.9921; Desired output: 1;  Error: -0.0079;
Input: 0.9; 0.4;  Output: 0.9997; Desired output: 1;  Error: -0.0003;
Input: 1; 0.4;  Output: 1; Desired output: 1;  Error: -0;
Input: 0.1; 0.6;  Output: 0; Desired output: 0;  Error: 0;
Input: 0.2; 0.6;  Output: 0.0001; Desired output: 0;  Error: 0.0001;
Input: 0.3; 0.6;  Output: 0.0003; Desired output: 0;  Error: 0.0003;
Input: 0.4; 0.6;  Output: 0.002; Desired output: 0;  Error: 0.002;
Input: 0.5; 0.6;  Output: 0.0296; Desired output: 0;  Error: 0.0296;
Input: 0.6; 0.6;  Output: 0.404; Desired output: 0;  Error: 0.404;
Input: 0.7; 0.6;  Output: 0.8827; Desired output: 1;  Error: -0.1173;
Input: 0.8; 0.6;  Output: 0.9705; Desired output: 1;  Error: -0.0295;
Input: 0.9; 0.6;  Output: 0.9906; Desired output: 1;  Error: -0.0094;
Input: 1; 0.6;  Output: 0.9981; Desired output: 1;  Error: -0.0019;
Input: 0.1; 0.8;  Output: 0; Desired output: 0;  Error: 0;
Input: 0.2; 0.8;  Output: 0; Desired output: 0;  Error: 0;
Input: 0.3; 0.8;  Output: 0; Desired output: 0;  Error: 0;
Input: 0.4; 0.8;  Output: 0.0001; Desired output: 0;  Error: 0.0001;
Input: 0.5; 0.8;  Output: 0.0037; Desired output: 0;  Error: 0.0037;
Input: 0.6; 0.8;  Output: 0.0948; Desired output: 0;  Error: 0.0948;

Input: 0.7; 0.8;  Output: 0.5267; Desired output: 1;  Error: -0.4733;
Input: 0.8; 0.8;  Output: 0.8385; Desired output: 1;  Error: -0.1615;
Input: 0.9; 0.8;  Output: 0.9365; Desired output: 1;  Error: -0.0635;
Input: 1; 0.8;  Output: 0.9715; Desired output: 1;  Error: -0.0285;
Input: 0.1; 1;  Output: 0; Desired output: 0;  Error: 0;
Input: 0.2; 1;  Output: 0; Desired output: 0;  Error: 0;
Input: 0.3; 1;  Output: 0; Desired output: 0;  Error: 0;
Input: 0.4; 1;  Output: 0.0002; Desired output: 0;  Error: 0.0002;
Input: 0.5; 1;  Output: 0.0024; Desired output: 0;  Error: 0.0024;
Input: 0.6; 1;  Output: 0.0112; Desired output: 0;  Error: 0.0112;
Input: 0.7; 1;  Output: 0.0267; Desired output: 0;  Error: 0.0267;
Input: 0.8; 1;  Output: 0.0505; Desired output: 0;  Error: 0.0505;
Input: 0.9; 1;  Output: 0.0997; Desired output: 0;  Error: 0.0997;
Input: 1; 1;  Output: 0.2201; Desired output: 0;  Error: 0.2201;
Total Mean Square Error: 0.011548954454218788
```

Figure 4. 33: Total Mean Square Error

Step 9: Testing the Neural Network with input.

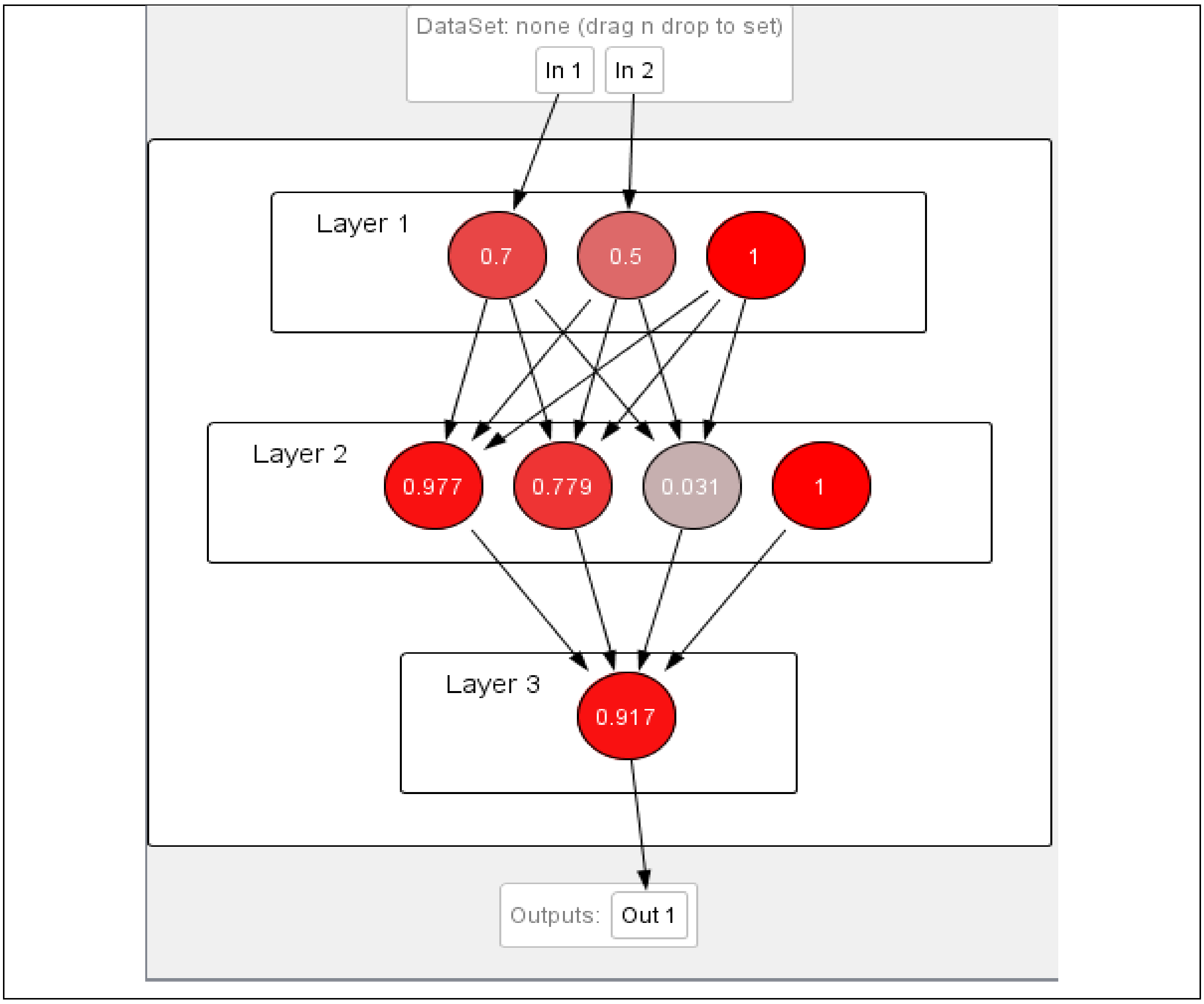


Figure 4. 34: Testing Neural Network

The value of the output neuron is close to 1, which is the desired output for the given input. The small difference represents the acceptable error.

Code Snippets

The section below shows some of the major code snippets together with a brief explanation.

Table 4. 9: Code Snippets – Part 1

Code Snippets	**Explanation**
`import java.sql.Connection;` `import java.sql.DriverManager;` `import java.sql.PreparedStatement;` `import java.sql.ResultSet;` `import org.neuroph.core.NeuralNetwork;` `import java.sql.SQLException;` `import java.util.logging.Level;` `import java.util.logging.Logger;` `import javax.swing.JOptionPane;`	Importing the libraries used including Neuroph.
`public static void Neural(double s, double t, int ID) throws SQLException {` `    NeuralNetwork myNeuralNetwork = NeuralNetwork.load("C:\\Users\\Akshay\\Documents\\"` `            + "NetBeansProjects\\dissert\\Neural Networks\\AdaptiveLearning.nnet");` `    myNeuralNetwork.setInput(s, t);` `    myNeuralNetwork.calculate();` `    double[] networkOutput = myNeuralNetwork.getOutput();`	Codes to load the neural network into application and setting inputs.
`    while (rs.next()) {` `        previous_lev = rs.getInt("Level");` `    }` `    if (networkOutput[0] > 0.5) { //Student Passed the test` `        if (previous_lev == 5) {` `            JOptionPane.showMessageDialog(null, "Congratulations you have completed the curriculum for this module");` `        } else {` `            previous_lev = previous_lev + 1;` `            JOptionPane.showMessageDialog(null, "Promoted to Next Level");` `        }`	Codes to retrieve level of student and manipulate the result from the neural network.

```java
} else {
    if (networkOutput[0] < 0.5) { //Student Failed the test
        //Code Below to implement the weightage algorithm
        String sql3 = "select Marks from score where test_type=\"PostTest1\" AND studentID='" + ID + "' ";
        PreparedStatement ps3 = con.prepareStatement(sql3);
        ResultSet rs3 = ps3.executeQuery();
        if (rs3.next()) {
            m1 = rs3.getInt("Marks");
        } //Setting the marks for PostTest1 to the Min Pass mark if ever
          //the student has started the curriculum on Level 2 */
        else {
            m1 = 70;
        }

        String sql4 = "select Marks from score where test_type=\"PostTest2\" AND studentID='" + ID + "' ";
        PreparedStatement ps4 = con.prepareStatement(sql4);
        ResultSet rs4 = ps4.executeQuery();
        while (rs4.next()) {
            m2 = rs4.getInt("Marks");

        }
        String sql5 = "select Marks from score where test_type=\"PostTest3\" AND studentID='" + ID + "' ";
        PreparedStatement ps5 = con.prepareStatement(sql5);
        ResultSet rs5 = ps5.executeQuery();
        while (rs5.next()) {
            m3 = rs5.getInt("Marks");
        }
        String sql6 = "select Marks from score where test_type=\"PostTest4\" AND studentID='" + ID + "' ";
        PreparedStatement ps6 = con.prepareStatement(sql6);
        ResultSet rs6 = ps6.executeQuery();
        while (rs6.next()) {
            m4 = rs6.getInt("Marks");
        }
```

List of code to retrieve the previous performances of the student from the database

`` if (previous_lev == 1) { JOptionPane.showMessageDialog(null, "Repeat level"); } else if (previous_lev == 2) { avg_per = (m1 * w1) / w1; System.out.print("average is " + avg_per); if (avg_per > 75) { JOptionPane.showMessageDialog(null, "Repeat same level"); } else { previous_lev = previous_lev - 1; JOptionPane.showMessageDialog(null, "Back to Previous Level"); } } else if (previous_lev == 3) { avg_per = ((m1 * w1) + (m2 * w2)) / (w1 + w2); if (avg_per > 75) { JOptionPane.showMessageDialog(null, "Repeating Level"); } else { previous_lev = previous_lev - 1; JOptionPane.showMessageDialog(null, "Back to Previous Level"); } } else if (previous_lev == 4) { avg_per = ((m1 * w1) + (m2 * w2) + (m3 * w3)) / (w1 + w2 + w3); if (avg_per > 75) { previous_lev = previous_lev; JOptionPane.showMessageDialog(null, "Repeating Level"); } else { previous_lev = previous_lev - 1; JOptionPane.showMessageDialog(null, "Back to Previous Level"); } } ```	Code to apply the algorithm if ever the student fails a test, the algorithm will take into account the previous performances of the student before either making him repeat a level or regressing to previous level
`` String sql2 = "UPDATE student SET Level= '" + previous_lev + "' WHERE studentID='" + ID + "' "; PreparedStatement ps2 = con.prepareStatement(sql2); int rs2 = ps2.executeUpdate(); } catch (SQLException ex) { Logger.getLogger(ChildProfile.class.getName()).log(Level.SEVERE, null, ex); } } ```	Code to update the new level of the student

Table 4. 10: Code Snippets – Part 2 (Input parameters in the neural network. (NeuralInput.java))

Code for Neural Input	Description of Code
`public class NeuralInput {` `public static void setResult(int score, int time, int StudID) throws SQLException {` `double norm_score = (score - 0) / (double) (100 - 0);` `double norm_time = (time - 10) / (double) (60 - 10);` `NeuralNet.Neural(norm_score, norm_time, StudID);` `}` `}`	Description of the code to input into the neural network. The score and time of the test and the Student ID will be the inputs.

5) A Visualisation and Feedback Module.

In the design and development of a SMART Learning Environment, one of the important features that researchers might tend to neglect is to come up with a proper module that allows the visualization of data and eventually be able to give proper feedback. This feature allows appropriate visualisation that eventually would help in delivering timely and appropriate feedback to the learner. Isolated learners, active learners and atypical learner behaviours can be tracked and remedial action can be provided if necessary.

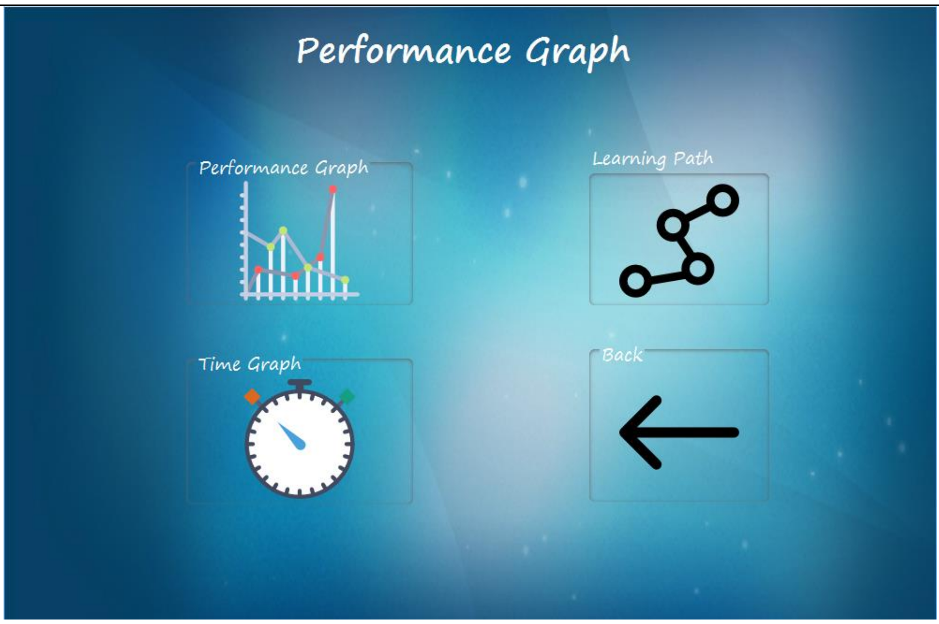


Figure 4. 35: Visualising performance of learners

Part of the code snippets used for implementing the visualisation module is shown in Table 4.11 below.

Table 4. 11: Code Snippets – Part 3

<table>
<tr><th>Code Snippets</th><th>Explanation</th></tr>
<tr><td><pre>
import com.mysql.jdbc.Connection;
import java.awt.BasicStroke;
import java.awt.BorderLayout;
import java.awt.Color;
import java.awt.Font;
import java.sql.DriverManager;
import java.sql.PreparedStatement;
import java.sql.ResultSet;
import java.sql.SQLException;
import java.util.logging.Level;
import java.util.logging.Logger;
import javax.swing.ImageIcon;
import javax.swing.JOptionPane;
import net.proteanit.sql.DbUtils;
import org.jfree.chart.ChartFactory;
import org.jfree.chart.ChartFrame;
import org.jfree.chart.ChartPanel;
import org.jfree.chart.JFreeChart;
import org.jfree.chart.axis.CategoryAxis;
import org.jfree.chart.axis.ValueAxis;
import org.jfree.chart.plot.CategoryPlot;
import org.jfree.chart.plot.PlotOrientation;
</pre></td><td>These libraries are needed to ensure that the graphs are generated successfully.</td></tr>
<tr><td><pre>
private void Update_Table() {

    try {

        String sql = "SELECT test_type as 'Test Type',Date FROM score "
                + "WHERE studentID='" + kclick + "'ORDER BY test_type ASC ";
        ps = conn.prepareStatement(sql);
        rs = ps.executeQuery();
        tblDate.setModel(DbUtils.resultSetToTableModel(rs));
        tblDate.setForeground(Color.BLACK);
        tblDate.getTableHeader().setFont(new Font("Segoe Print", Font.BOLD, 16));

    } catch (SQLException ex) {
        Logger.getLogger(ChildProfile.class.getName()).log(Level.SEVERE, null, ex);
    }

}
</pre></td><td>SQL statements to retrieve date on which the students have completed the test and its corresponding Test Type.</td></tr>
</table>

```java
private void btnperfgraphActionPerformed(java.awt.event.ActionEvent evt) {
    try {

        Update_Table();
        ImageIcon icon = new ImageIcon("C:/Users/Akshay/Desktop/Project Resources/background3.jpg");
        String query = "select test_type,Marks from score where studentID='" + kclick + "'"
                + "ORDER BY  test_type ASC ";
        JDBCCategoryDataset dataset = new JDBCCategoryDataset(conn, query);
        JFreeChart chart = ChartFactory.createLineChart("Performance", "Test", "Score",
                dataset, PlotOrientation.VERTICAL, false, true, true);
        LineAndShapeRenderer renderer = new LineAndShapeRenderer();
        renderer.setSeriesPaint(0, Color.RED);
        renderer.setSeriesStroke(0, new BasicStroke(2.0f));
        CategoryPlot plot = chart.getCategoryPlot();
        chart.setBackgroundPaint(Color.WHITE);
        chart.setBackgroundImage(icon.getImage());
        plot.setRenderer(renderer);
        CategoryAxis axis = plot.getDomainAxis();
        CategoryPlot p = chart.getCategoryPlot();
        ValueAxis axis2 = p.getRangeAxis();
        Font font3 = new Font("Tahoma", Font.BOLD, 15);
        plot.getDomainAxis().setLabelFont(font3);
        plot.getRangeAxis().setLabelFont(font3);
        Font font = new Font("Tahoma", Font.PLAIN, 15);
        axis.setTickLabelFont(font);
        Font font2 = new Font("Tahoma", Font.PLAIN, 15);
        axis2.setTickLabelFont(font2);
        ChartPanel pane = new ChartPanel(chart);
        jPanel2.setVisible(true);
        jPanel1.setLayout(new java.awt.BorderLayout());
        jPanel1.add(pane, BorderLayout.CENTER);
        jPanel1.setVisible(true);
        jPanel1.validate();
    } catch (Exception e) {
        JOptionPane.showMessageDialog(null, e);
```

Description of code to create the graph using JFreeChart library and setting the size, background and plotting the graph based on the SQL statements which is used to retrieve the student's marks and test type based on Student ID.

Further details of visualisation will be provided in the Demonstration Section of the DSRM Framework.

6) A Recommendation Module.

This module recommends to the learner the most appropriate learning strategies, activities and contents so as to reach desired level and objectives. Provision of specific learning materials to reinforce identified weaknesses of the learner is essential. As the learner progresses through the different levels and chapters of the CEH curriculum present on the SMART Learning Environment, digital traces are left by the learner which after being captured, can be analysed. These digital traces form the basis of Learning Analytics, which thereafter can be developed into actionable personalised recommendations which eventually support and motivate the learner to bring the best out of himself/herself. These recommendations, through the use of the SMART Learning Environment, proved to be meaningful and timely and help to address the inherent limitations of previous methods of providing feedback to learners which were at times delayed and not constructive. The risk level is determined by analysing low level of marks obtained in tests, not sufficient time spent on platform (determined by logs kept every time learner logs in and out) and the interaction of the learner with peers and instructor. The table below shows the threshold values used to calculate the level of risk.

Table 4. 12: Level of Risk of Learner

Severity of the risk	Threshold Value	Actions to be take
Critical	0.75 – 1.0	Notify learner and instructor
High	0.5 – 0.75	Notify learner
Average	0.25 – 0.5	Display progress of learner to show whether learner is progressing positively or digressing from goal set.
Low	0 – 0.25	No actions taken

Figure 4.36 below shows how the instructor and/or the learner are notified in case of risk identified as critical or high. For the sake of simplicity, situations where risk are identified as average or low have been omitted.

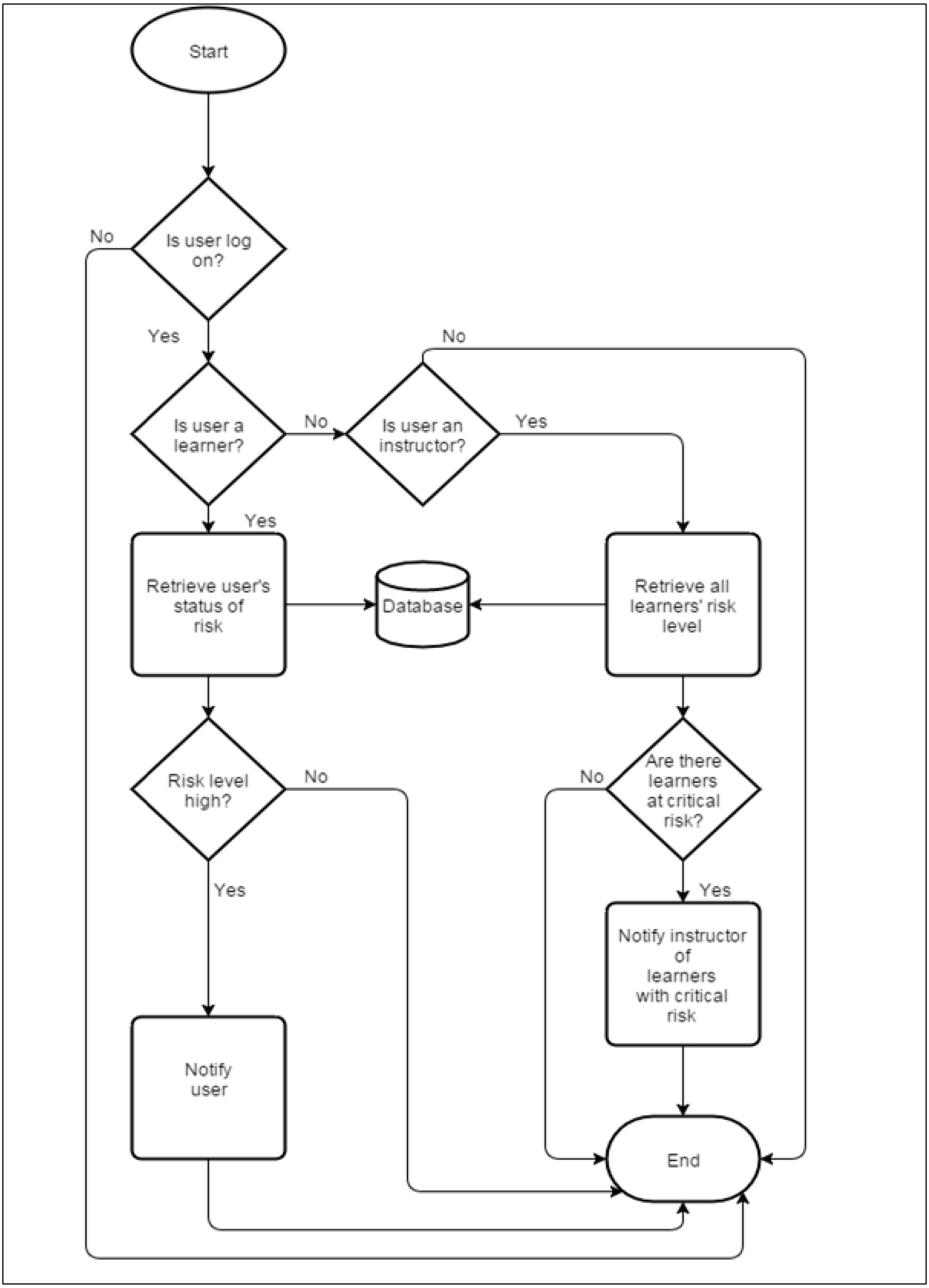


Figure 4. 36: Notification of Learners at risk

7) A Ubiquitous Computing Module.

This will help reach out to the learner and ensure that the learning process can take place anytime and anywhere. Important messages pertaining to the learner's interest, can be delivered anytime, anywhere to the learner's mobile device. Such type of communication can happen through Push, Pull or Mixed (a combination of Push and Pull) Technologies. Push-notification offers relatively flexible, autonomous, reliable and adaptable means of delivery of important notifications wherever the learner is. A number of notifications platform exist but for the purpose of this research, One Signal has been chosen. The latter can provide push notifications to be sent to all mobile devices and major native platforms including Java, where a number of (Application Program Interface) API is available. Besides One Signal also provides a single user interface. The main idea is to register the learner's device to One Signal push notification service. After connecting the device to One Signal, the latter will send a device ID to the application. This device ID will be unique to a device. It is this device ID which will be used to target specific device for push notification. This is shown in Figure 4.37.

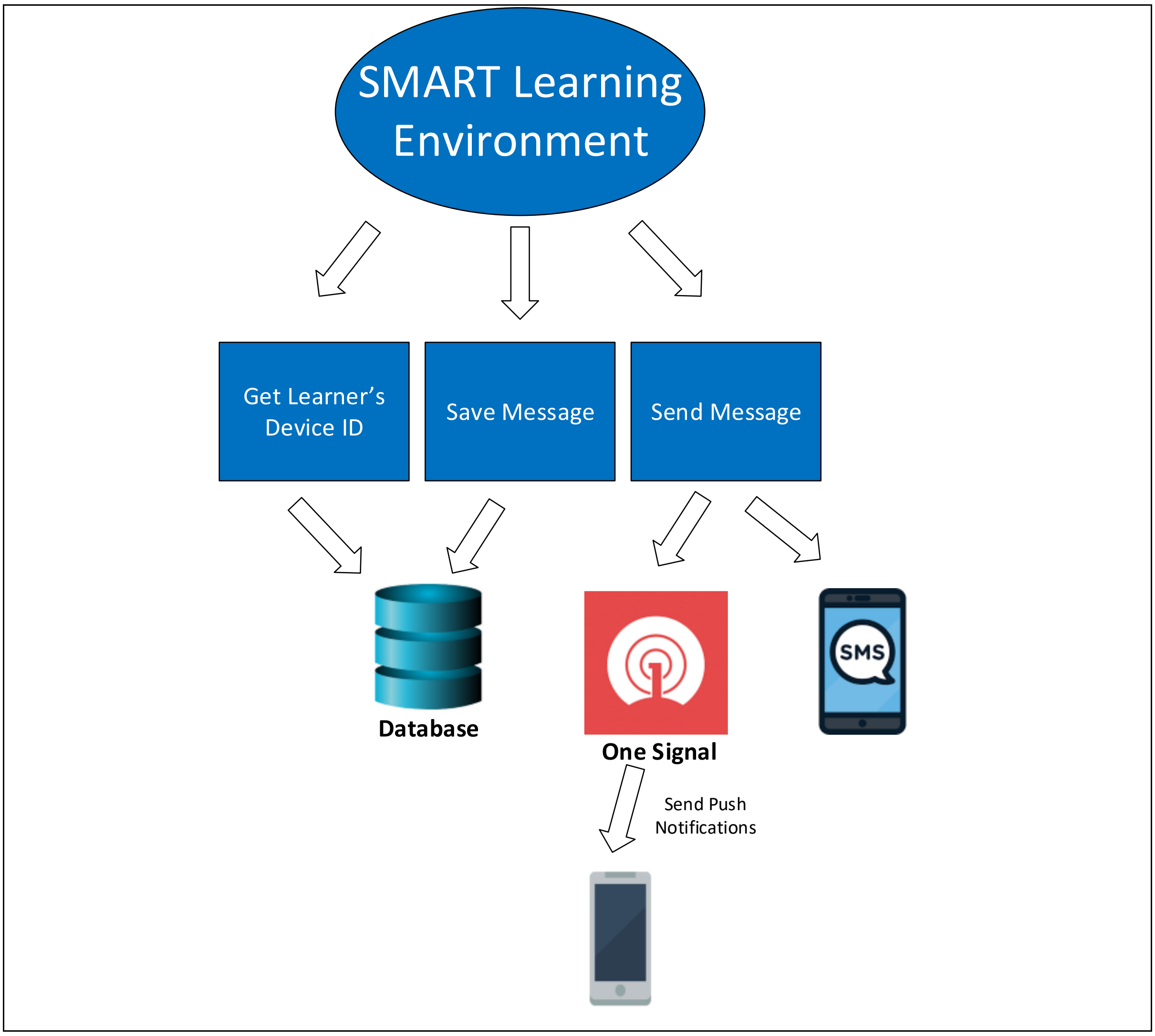


Figure 4. 37: Push Notification

4.2.4 Stage 4: Demonstration

The SMART Learning Environment was demonstrated and tested by a pre-test sample of 20 Cybersecurity Professionals for feedback and eventual refinement of the system. The 20 Cybersecurity professionals were randomly selected and involved professionals at all levels in the field of Cybersecurity.

Scenario under consideration

The demonstration was validated and verified by showing the different learning materials output by the SMART Learning Environment for Cybersecurity learners with different prior knowledge, thereby producing personalisation and adaptation of learning contents for more effective and efficient learning to take place. The scenario under consideration below is for a

Cybersecurity Professional at the level of Information Security Officer who would want to up-skill to the level of Information Security Analyst where a professional certification like Certified Ethical Hacker (CEH) is required. The roles and necessary skills of both the Information Security Officer and the Information Security Analyst is discussed in Chapter 2. Six levels of learning contents for the Certified Ethical Hacker (CEH) certification has been set for different learners with different combination of performances coupled with pre-test and post-test.

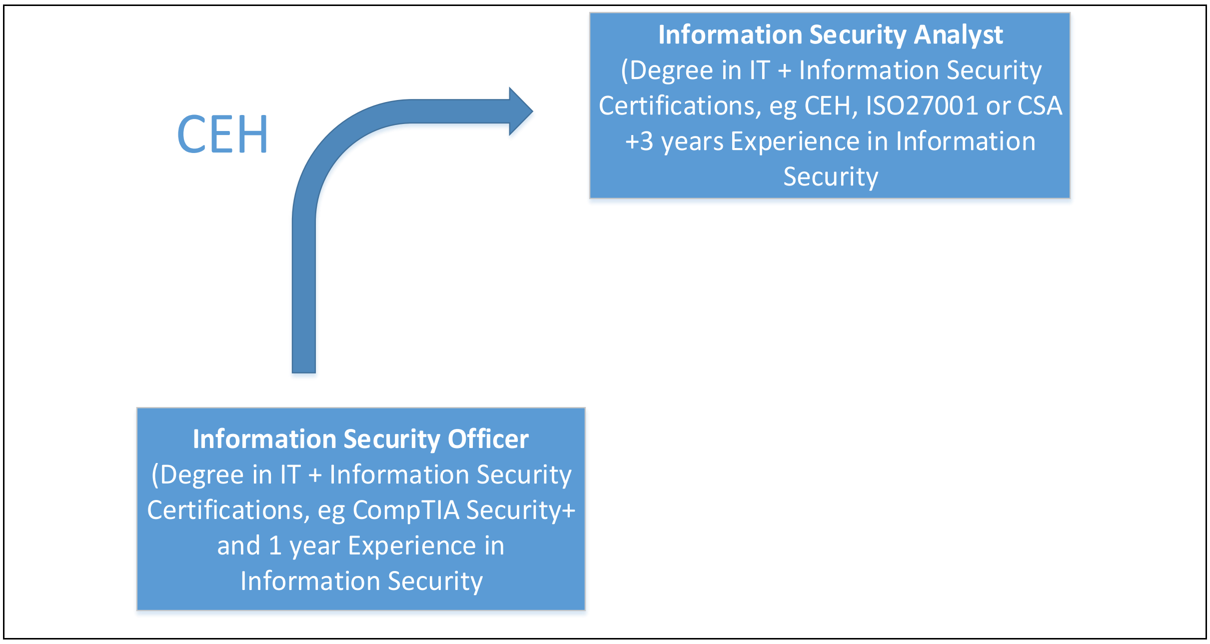


Figure 4. 38: Up-skilling from Information Security Officer to Information Security Analyst

(Source: Researcher's own construction)

Different Learners with different learning pathways

The SMART Learning Environment offers the possibility for learners to progress and evolve at their own pace, each of them having the possibility to take a different learning pathway or route. It has to be understood that each learner is unique. This shifts the control of choice from the trainer to the learner and ensures that the building of knowledge and skills is done progressively for the professional development of the learner. This sense of learner control gives the learner a feeling of empowerment and further boost the motivation of the learner. Furthermore, each time the learner progresses through a level, this represents a recognition of the progress of the learner towards the intended learning objectives and goals. An analogy that can be used to represent the different learning pathways for the different learners is that of a road trip that different drivers can take to reach a destination. Different drivers can take different routes but they will all reach the same destination. Here it is important to emphasize that just like drivers rely on road signs, similarly the learners rely on messages, feedback and instructions that would reassure the learners that they are on the right track. Here the role of the Instructional Designer is instrumental where it has to be ensured that the learning objectives are being met in a pedagogically safe environment.

Experimental Scenario 1

Learner X starts the Chapter 1 of the CEH course and is required to do a pre-test, which consists of a random set of questions from a pool and has a maximum of 30 seconds to answer each question. Learner X correctly answers 8 questions out of 10 in the pre-test and scores 80%. Since the learner has not attempted any of the post-tests, his scores for the post-tests are null.

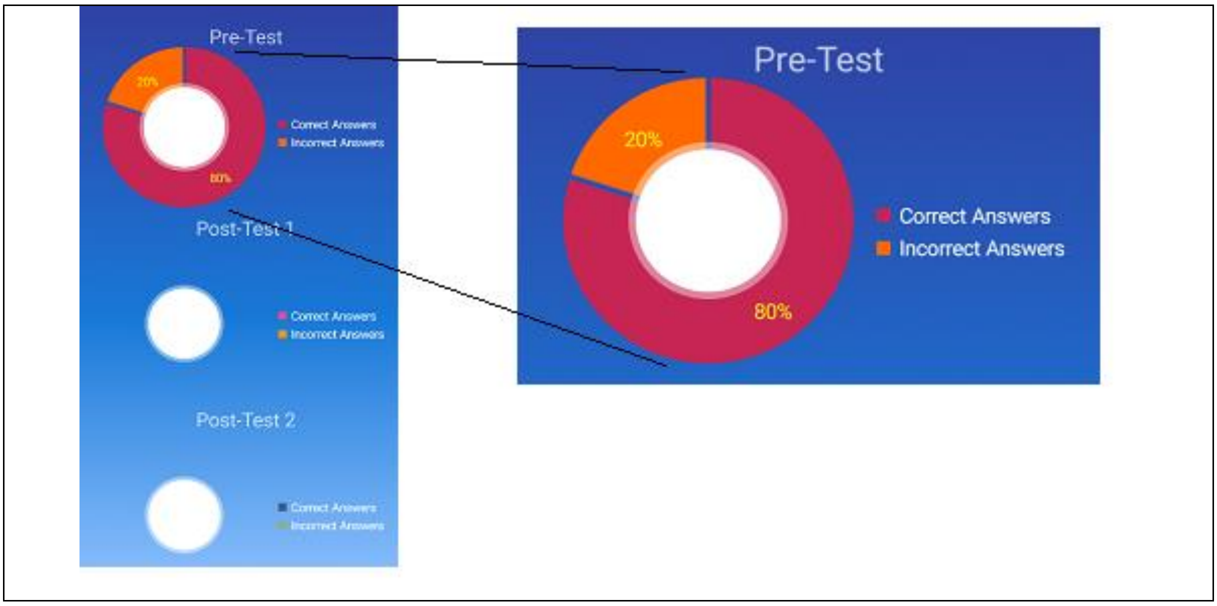


Figure 4. 39: Pre-Test for Learner X

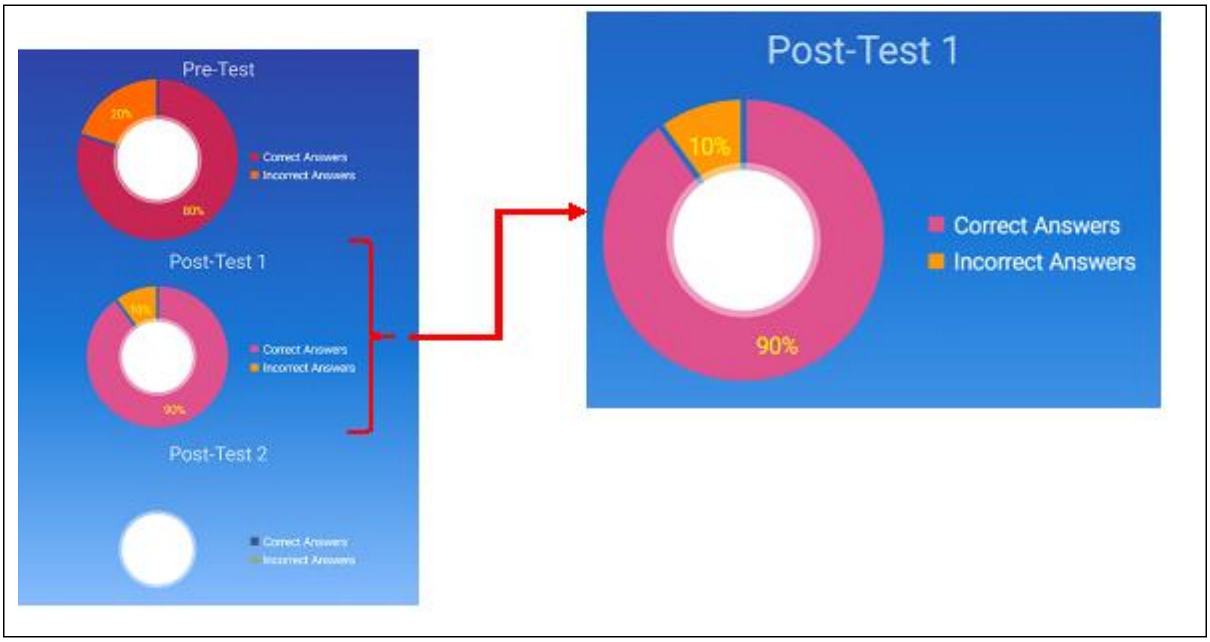


Figure 4. 40: Post-Test1 for Learner X

Learner X then attempts post-test1 (for Level 1) where he score 90% and post-test2 (for Level 2) where he scores 70% and a post-test3 (for Level 3) where he scores 90%. Eventually the SMART Learning Environment generates a graph to depict the performance of the learner and builds a profile about the learner. Since the learner scores above 70% in his tests, the systems tags him as a brilliant learner.

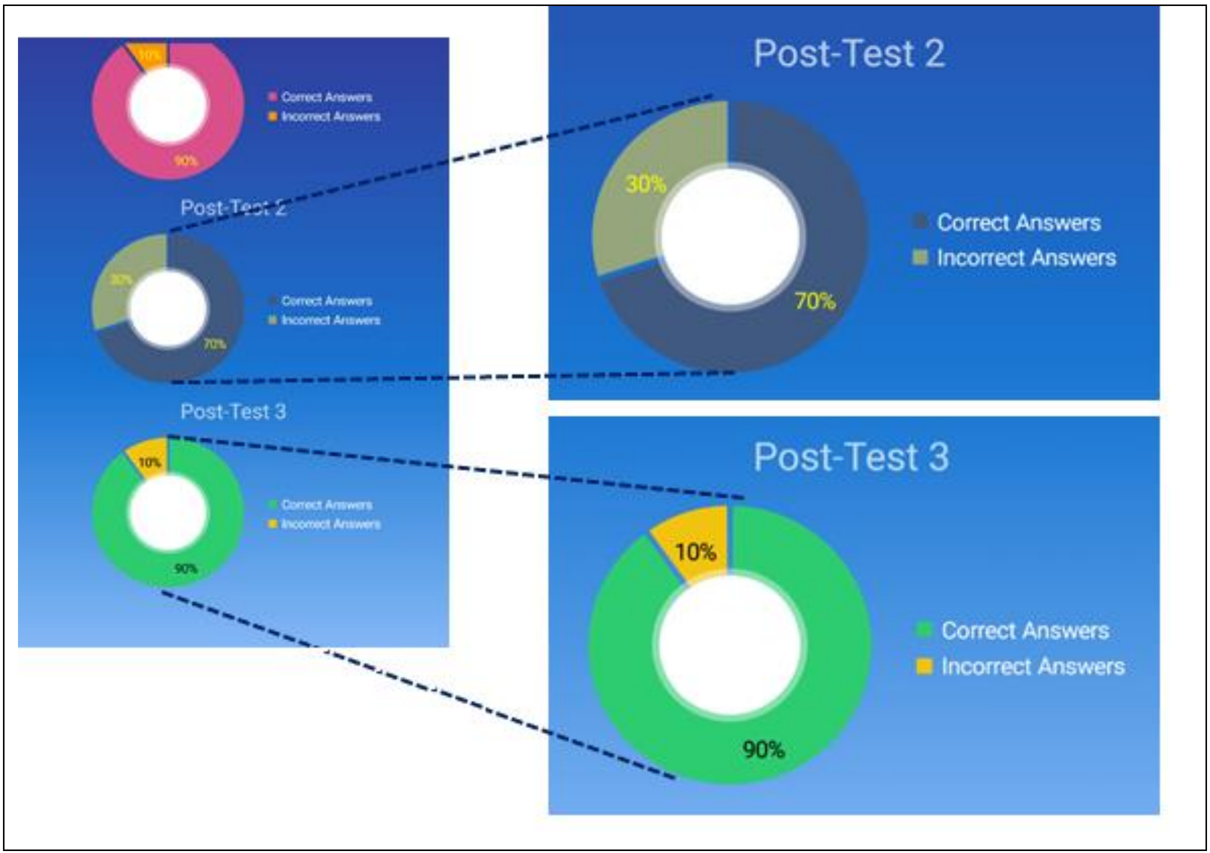
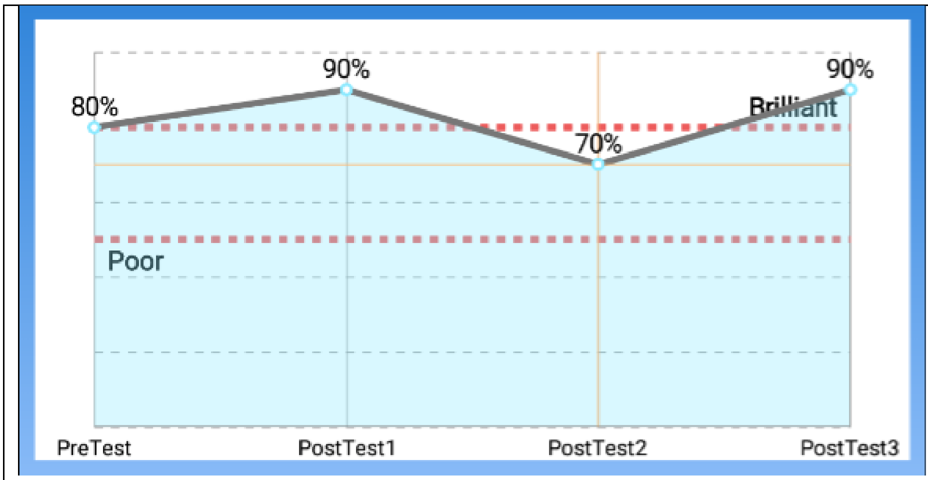


Figure 4. 41: Post-Test 2 and 3 for Learner X



The graph shows the marks that a specific learner has obtained during the tests carried out (pre-test and post-test) and is indicative about the progress of the learner

Figure 4. 42: Visualising performance of learner X

The learning pathway which can also be described as the learning routes or learning flows and allows the learner to dynamically evolve through the learning contents.

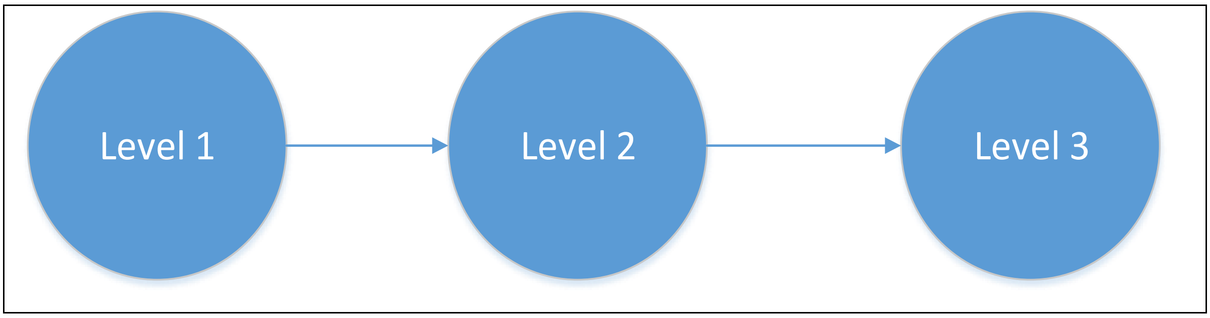


Figure 4. 43: Learning Pathway for Learner X

Experimental Scenario 2

Learner Y, based on his score obtained and time taken, has been tagged as an average learner by the SMART Learning Environment. His progress through the learning materials is depicted in the table below.

Table 4. 13: Performance of Learner Y

Tests	Pre-Test	Post-Test1	Post-Test2	Post-Test2	Post-Test3
Marks	6	7	3	6	6

It is observed that Learner Y, on his first attempt, fails Post-Test 2 and is required to do Post-Test 2 again. Appropriate learning materials from level 2 is provided in the form of consolidation materials for Learner Y and the latter is also provided with supplementary learning activities. Learner Y then retakes Post-Test 2 again where he successfully clears this level and then takes post-test 3 where he passes the test.

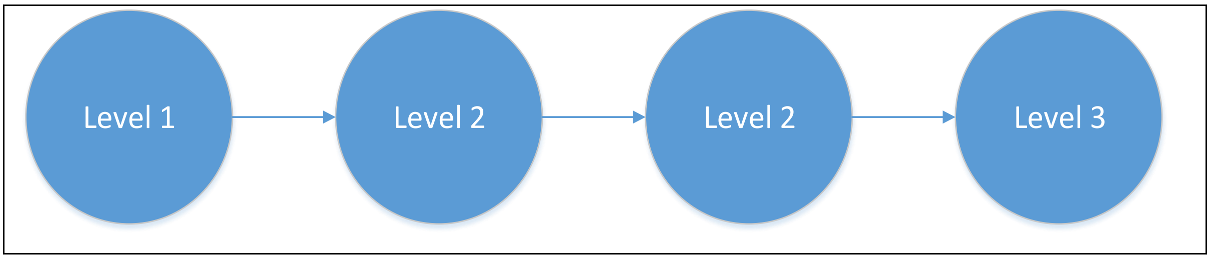


Figure 4. 44: Learning Pathway for Learner Y

Experimental Scenario 3

Learner Z is categorised as weak as per his performance shown below.

Table 4. 14: Performance of Learner Y

Test	Pre-test	Post-Test1	Post-Test1	Post-Test2	Post-Test3	Post-Test3	Post-Test3
Marks	3	3	5	5	2	3	6

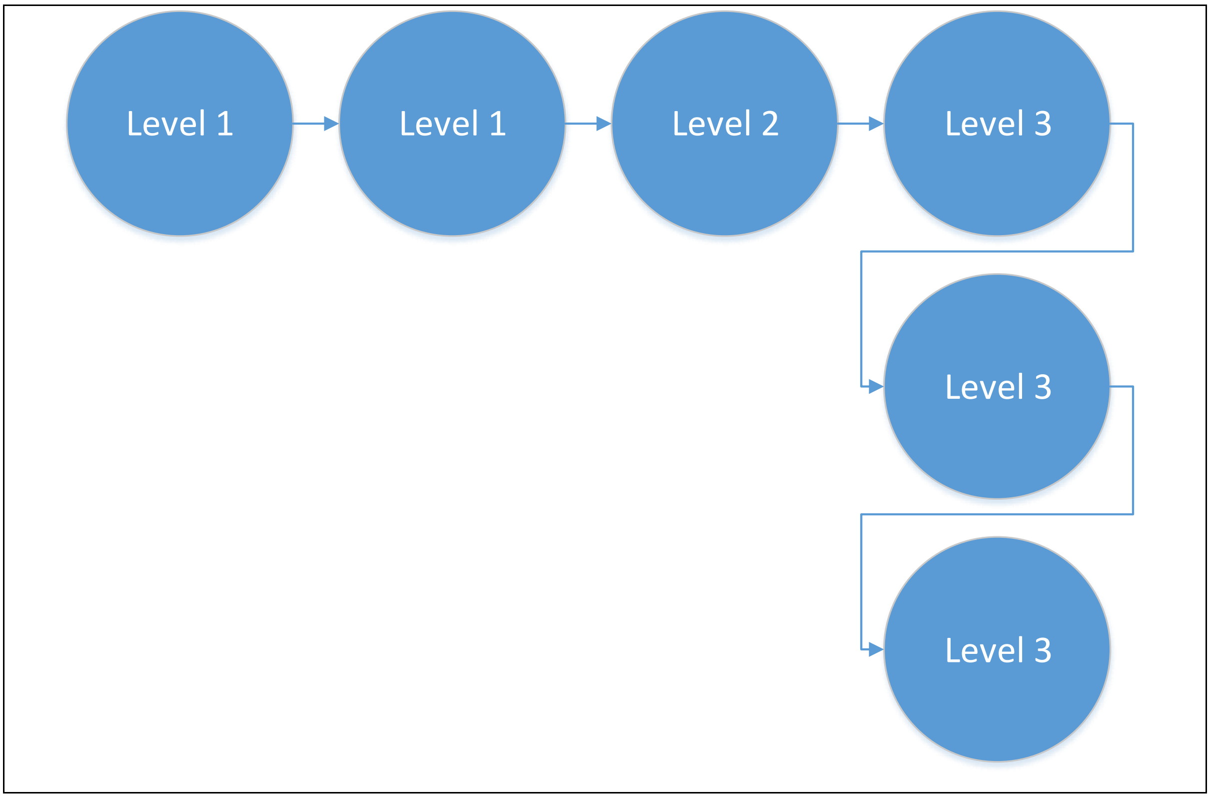


Figure 4. 45: Learning Pathway for Learner Z

It is being observed that Learner Z is definitely a weak learner and clears post-test 3 with much difficulty after 3 attempts. The SMART Learning Environment provides Learner Z with elementary materials (which are identified through the use of tagging applied to learning objects) and further consolidates on the learning process of Learner Z by making him carry out a number of learning activities for the level he fails to clear.

4.2.5 Stage 5: Evaluation

Qualitative feedback from the pre-test sample of 20 Cybersecurity Professionals was collected through the use of a pre-test questionnaire (refer to Annexure B) in order to further iteratively refine the system and reach a consensus before the system can be demonstrated to and tested by a wider audience. The evaluation framework focused mostly on the effectiveness of the SMART Learning Environment in providing personalised learning content (correctness) and its usability.

4.2.5.1 Summary of the feedback obtained during Evaluation Exercise

The evaluation exercise by the pre-test sample served more as a focus group discussion where constructive feedback was collected before the actual testing with the sample population was done. This exercise eventually served to iteratively refine the product, which in this case is the SMART Learning Environment. Table 4.15 and table 4.16 below summarise the main findings from this exercise.

Table 4. 15: Summary of Feedback: Ease of Use

Ease of Use		
Describe your experience with the ease of use of the SMART Learning Environment	What changes would you make to improve the ease of use?	Comment on your satisfaction with the user interface. Does it promote easy use?
- The SMART Learning Environment is easy to use and intuitive. *(Respondent 6)*	- More elaborate learner instructions to better help them understand what is expected from them and how to attempt the pre-tests, tests and post-tests and the rationale behind having these in the learning process. *(Respondent 15)*	- When designing such systems, Software Ergonomics is a key concept. This ensures that the SMART Learning Environment which is being developed fit the people who will be using it. It involves understanding the user needs, interface design, usability testing and

		providing the necessary support. In this case, it can be said that Software Ergonomics has been properly taken into consideration and that the SMART Learning Environment promotes easy use. *(Respondent 4)*
- The SMART Learning Environment provides easy navigation and the learner feels at ease with the system, *(Respondent 11)*	- When certain operations are being processed, the user does not know how much time is left for the action to be completed. This leaves the user in a state where he/she is lost or not sure whether the system has frozen. It is advisable to have a progress bar so that the user can visualise the progress of the operation. *(Respondent 7)*	- Definitely, one of the best features of the system in terms of user interface is the visual representation of the progress of the learner *(Respondent 1)*
- The interaction with the SMART Learning Environment was one that required minimal effort. This can be one of the factors that will determine its usage, especially when we would want the learning process to be seamlessly incorporated in the daily routine of Cybersecurity professionals for	- One issue that is being observed is that there are certain missing links to the home page from certain screens. This should be addressed in the next iteration. *(Respondent 3)*	- The system is engaging and easy to use. *(Respondent 12)*

their constant upskilling. *(Respondent 19)*		
- The SMART Learning Environment is easy to learn. *(Respondent 5)*	- The instructions to the learner are in certain situations used in a font that is too small. This should be enlarged to make the instructions more readable. *(Respondent 19)*	- The look and feel of the SMART Learning Environment is nice and encourages any user to further explore the system. *(Respondent 14)*

Table 4. 16: Summary of Feedback: Functionality and Capability of the Smart Learning Environment

Functionality and Capability of the Smart Learning Environment		
Discuss your satisfaction with the effectiveness of the SMART Learning Environment in providing personalised and adapted learning materials for a more effective learning experience as opposed to existing methods for continuous learning.	Comment on the correctness of the SMART Learning Environment	Comment on possible improvements to the proposed SMART Learning Environment
- As opposed to existing methods of learning, the SMART learning Environment provides an interesting approach whereby the learning process is tailor-made and probes the learner to bring the best of himself/herself. *(Respondent 4)*	- The different experimental scenarios highlighted during the pre-test exercise was really interesting and depicted how different learners with different background are able to progress through the system. It can be said that the system is correct in	- A mobile version of the SMART Learning Environment can prove to be handier but it is understood that this is not the core of the research. *(Respondent 6)*

	providing a personalised learning experience. *(Respondent 3)*	
- Contemporary methods of learning are not really suitable for working professionals. This approach of learning is interesting in the sense that it accounts for the fact that working professionals are busy persons and that each of them have different backgrounds and have different targets. *(Respondent 11)*	- The SMART Learning Environment adapts the content according to the background of the learner and hence can be termed as correct and performing as per its expectations. *(Respondent 18)*	- The ability to interface the SMART Learning Environment with existing Learning Content Repositories or MOOCs. *(Respondent 20)*
- The proposed SMART Learning Environment may perhaps represent the future of learning whereby there is a blend of technology, pedagogy and learning. *(Respondent 9)*	- The series of operations of the SMART Learning Environment are correct and logically sound and the results output are also correct. *(Respondent 1)*	- The use of Open Educational Resources for the SMART Learning Environment and then eventually opening it for the public at large. *(Respondent 16)*

4.2.5.2 Correctness

As depicted by the above experimental scenarios and feedback obtained during the evaluation exercise, the SMART Learning Environment provided the appropriate personalisation of learning materials and can hence be viewed as correct based on the scope set for this research. The pre-test sample of Cybersecurity professionals agreed on the correctness of the system and thought it would be great to further expand this concept to include other learning materials of Cybersecurity other than that of CEH.

4.2.5.3 Usability

Usability of the SMART Learning Environment can be seen as a quality attribute that describes how easy the user interfaces and the system as a whole are to use. It forms part of User Experience Design and ensures that the user does not encounter any difficulty or strain while using the system or interfaces. Usability does not only imply that the interface or system should be easy or simple to use. Efficiency, effectiveness and ultimately user satisfaction are important aspects to be considered so that the system is usable from a holistic point of view. It can be said that Usability is human-centered and this brings the whole importance of having this pre-test with a sample of 20 Cybersecurity Professionals. The feedback that was collected was that the SMART Learning Environment is easy to use and from a usability point of view is up to the expectations of the users. The users really liked the graphical components that show the progress of the learner over a specific period of time and felt that this was very helpful. The following are possible improvements and suggestions put forward by the pre-test sample of Cybersecurity Professionals which were eventually addressed in the iterative refinement processed carried out through the DSRM process:

- More elaborate learner instructions to better help them understand what is expected from them and how to attempt the pre-tests, tests and post-tests and the rationale behind having these in the learning process.
- A progress bar in case the system is being slow to respond.
- Larger font sizes in certain circumstances.
- Better navigation in certain situations by ensuring that the learner is able to come back to the home page.

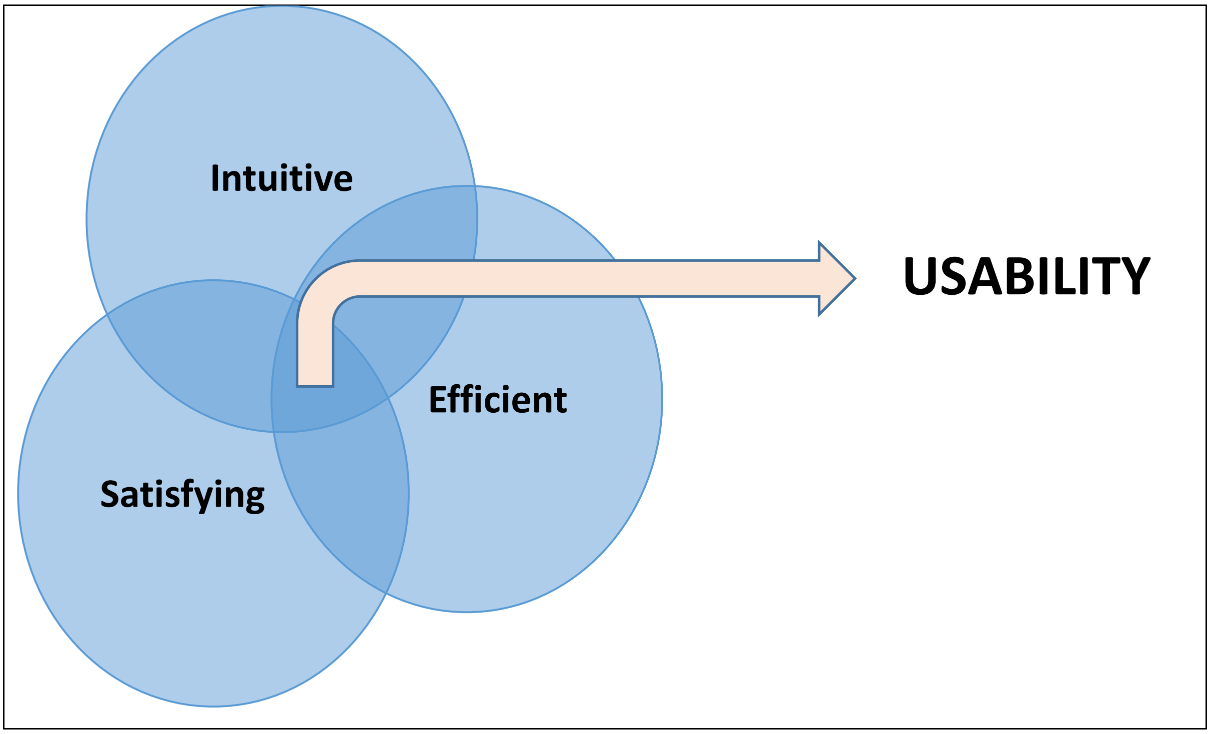


Figure 4. 46: Usability

4.2.5.4 Conclusion of the Evaluation

As part of the evaluation process, the SMART Learning Environment has been tested with a pre-test sample of 20 independent Cybersecurity Professionals operating at different levels in the area of Cybersecurity. The feedback they provided was very constructive and encouraging. Overall the SMART Learning Environment proved to be working correctly, providing trustworthy results and above all, providing an engaging and enriching learning experience. As a whole, the SMART Learning Environment has been positively accepted by the sample population and their suggestions and comments were taken on board so as to thereafter iteratively refine the system. The relevance of having such a SMART Learning Environment for the Cybersecurity community was unanimously acknowledged and suggestions were made to as to further extrapolate this concept to other areas of IT such as programming, where there is also a dire need of good programmers. It can be said that the artefact proposed, which is in the form of a SMART Learning Environment, supports a solution to the problem identified, and therefore satisfies stage 5 of the DSRM process.

4.2.6 Stage 6: Communication

This stage is important so as to diffuse the knowledge acquired and is seen as the last stage of the DSRM framework and happens once it is ensured that there is no further iteration to the previous stages is required in view of refining the proposed system. This stage also involves communicating the research problem identified, its importance, the proposed solution/artifact in the form of the SMART Learning Environment, the utility of the proposed SMART Learning Environment and the rigour in the development process to audiences including the academic community and professionals in the industry. The thesis itself in some form contributes to the communication stage. Conference papers and journal papers also help towards the communication requirements of the DSRM framework. The researcher also intends to hold workshops and seminars to brief the different stakeholders involved in this research, namely the academia, business and government about the effectiveness and novelty of the proposed solution used to address a problem of national importance.

4.3 Chapter Summary

This chapter presented the design and development of the SMART Learning Environment using the DSRM framework which proved to be very useful and rigorous approach for the development of Information Systems. The different stages of the DSRM framework were carefully studied so as to map the development process on the DSRM framework. In the end, it can be said that the proposed solution, in the form of the SMART Learning Environment, proved to be a viable one, which has been accepted by the pre-test sample of Cybersecurity Professionals. It can also be said that through the DSRM process, the SMART Learning Environment developed, proved to be of high quality, robust, reliable, correct and usable.

CHAPTER FIVE: PRESENTATION OF SURVEY RESULTS AND DISCUSSION

5.1 Introduction

This chapter presents the findings from the survey carried out with the sample of 63 Cybersecurity professionals in Mauritius. A copy of the survey can be found in Annexure E and visual representations of the survey results found in Annexure I. Chapter 5 starts by presenting the results of the survey followed by some discussions. The results and discussions were presented under different sections (Sections A-G) as per the outline of the questionnaire. Section A covered Demographic Information of the respondents. Section B helped shed light on the current situation prevailing in Mauritius in line with the research questions set out in Chapter 1. Section C covered the 'Perceived Ease of Use of the SMART Learning Environment'. Section D tackled the 'Perceived Usefulness of the SMART Learning Environment'. Section E investigated the 'Attitude towards Using the SMART Learning Environment''. Section F examined the 'Intention to Use the SMART Learning Environment' and Section G captured any future improvements in terms of suggestions from the respondents. The questionnaire has been designed bearing in mind the constructs on the Technology Acceptance Model (TAM).

5.2 Presentation of Results

The results of the survey are shown below and are classified according to the relevant sections in the survey questionnaire.

5.2.1 Section A: Demographic Information

The section that follows presents the results pertaining to demographic Information.

Table 5. 1: Role in the field of Cybersecurity

Current role	**Number**	**Percentage (%)**	
Information Security Officer	24	38.10	**1**
Information Security Analyst	20	31.75	**2**
Information Security Consultant	11	17.46	**3**
Chief Information Security Officer	3	4.76	**4**
Others (Please specify)	5 (Answers obtained from the survey included Network Security	7.94	**5**

	Administrator, IT Security Engineer and IT Security Specialist.		
Total	63	100	

Table 5. 2: Current Qualifications

Qualifications	**Number**	**Percentage**	
Certificate	0	0	**1**
Diploma	0	0	**2**
Degree	40	63.49	**3**
Postgraduate	22	34.92	**4**
Other (Please specify)	1 (PhD)	1.59	**5**

Table 5. 3: Certifications followed

Certifications	**Number**	
Certified Information Systems Security Professional (CISSP)	8	**1**
Certified Ethical Hacker (CEH)	28	**2**
Licensed Penetration Tester (LPT)	5	**3**
Certified Information Security Manager (CISM)	6	**4**
Certified Cloud Security Professional (CCSP)	3	**5**
EC-Council Certified Security Analyst (ECSA)	2	**6**
CompTIA Security+	40	**7**
Certified Network Defender Certification (CND)	5	**8**
Offensive Security Certified Professional (OSCP)	2	**9**
Others (Please specify)	5 Certified Information Systems Auditor (CISA), ISO27001	**10**

Table 5. 4: Employment Type

Employment Type	Number	Percentage
Permanent	23	36.51
Contract	40	63.49

Table 5. 5: Age Group

Age Group	Number	Percentage	
18-30	24	38.10	**1**
31-40	22	34.92	**2**
41-50	10	15.87	**3**
51-60	6	9.52	**4**
Above 60	1	1.59	**5**

Table 5. 6: Gender

Gender	Number	Percentage
Male	36	57.14
Female	27	42.86
Total	63	100.00

Table 5. 7: Years of Experience

Years of Experience in the field of Cybersecurity	Number	Percentage	
0-5	28	44.44	**1**
6-10	17	26.98	**2**
11-15	10	15.87	**3**
15-20	7	11.11	**4**
More than 20	1	1.59	**5**

Discussions

From demographic data collected, it can be said that the majority of the Cybersecurity professionals in Mauritius are at an early stage of their career. This statement can be supported by the fact that the majority of them is within the age range of 18-40 (73.02% of the respondents from the chosen sample) and have been in the field of cybersecurity for less than 10 years (71.42% of the respondents). It is also a fact that Cybersecurity in Mauritius is a fairly new field as compared to areas such as software development or networking. Thus, it is not surprising that the majority of Cybersecurity professionals are either Information Security Officer or Information Security Analyst and are still growing professionally. Most of the Cybersecurity professionals have followed certification related to cybersecurity, out of which Certified Ethical Hacker (CEH) is the most popular one (44.44% of the sample has followed

CEH). It can also be observed that the majority of these professionals are employed on a contractual basis and on probing further, it was understood that these employees need to follow professionals certifications and get certified before they can aspire to be transferred to permanent establishment. This adds a whole new dimension to the importance of following professional certifications for these cybersecurity professionals. It is also observed that all of the respondents surveyed have at least a first degree in computer-related subjects and this concords with the information given in Figure 1.6 of this thesis where it was identified that to start a career in Cybersecurity, at least a degree in IT is one of the essential conditions. It can also be said that a slight majority of the professionals in the field of Cybersecurity are males (57.14%). As an analogy, it can be said that just like small plants need to be watered regularly so that they develop strong roots and aspire to become strong trees, these Cybersecurity professionals being at an early stage of their career, need to be given necessary professional training and experience so that they grow into knowledgeable and confident Cybersecurity professionals.

5.2.2 Section B: Understanding the current situation

This section presents the results to questions set in order for the researcher to further understand the current situation and to shed light on the research questions set in Chapter 1.

Table 5. 8: Understanding the current situation

	1	**2**	**3**	**4**	**5**	
Statement	**Strongly Disagree**	**Disagree**	**Not Sure**	**Agree**	**Strongly Agree**	**Total**
1. Cybersecurity is a highly dynamic field	0	0	0	7 (11.11%)	56 (88.89%)	63 (100%)
2. There is a growing need for Cybersecurity experts in Mauritius	0	0	0	9 (14.29%)	54 (85.71%)	63 (100%)
3. Up-skilling and re-skilling in the field of Cybersecurity are important.	0	0	0	3 (4.76%)	60 (95.24%)	63 (100%)
4. Current techniques used for continuous learning in your company are effective.	15 (23.81%)	35 (55.56%)	8 (12.70%)	4 (6.35%)	1 (1.59%)	63 (100%)
5. You feel confident about your skills required at work.	2 (3.17%)	14 (22.22%)	25 (39.68%)	16 (25.40%)	6 (9.52%)	63 (100%)

Discussions

This section has enabled the researcher to further grasp the existing situation prevailing in the field of Cybersecurity in Mauritius by having feedback from the sample surveyed. Indeed this has consolidated the already existing opinion gathered during the desk studies and the Expert Reference Group Discussion carried out earlier. All participants have either agreed or strongly agreed that Cybersecurity is a highly dynamic field and that there is a growing need of professionals in this area in Mauritius. All participants also agreed or strongly agreed that continuous professional development in the form of up-skilling and re-skilling is essential in order to remain competitive in this highly dynamic field. Participants also gave the impression that current techniques for continuous learning in their company or workplace are not effective (79.37% of respondents pointed out the ineffectiveness of current techniques for continuous learning). From the data collected, it can also be deduced that a large portion of the respondents are not sure and certain about whether they have the necessary skills required at their respective workplace (40% of the respondents are not sure) and 25.39% of the respondents argue that they do not feel confident about their skills in their respective workplace.

5.2.3 Section C: Perceived Ease of Use of the SMART Learning Environment

This section highlights the results as far as 'Perceived Ease of Use' of the SMART Learning Environment is concerned.

Table 5. 9: Perceived Ease of Use of the SMART Learning Environment

	1	**2**	**3**	**4**	**5**	**Total**
Statement	**Strongly Disagree**	**Disagree**	**Not Sure**	**Agree**	**Strongly Agree**	
1. The User Interface of the SMART Learning Environment promotes easy use.	1 (1.59%)	5 (7.94%)	8 (12.70%)	35 (55.56%)	14 (22.22%)	63 (100%)
2. The SMART Learning Environment is easy to use.	1 (1.59%)	3 (4.76%)	6 (9.52%)	37 (58.73%)	16 (25.40%)	63 (100%)

Discussions

The *Perceived Ease of Use* (PEOU) of the SMART Learning Environment is one of the factors that influences the Cybersecurity professionals' intention to use the system. The user should feel that while using the SMART Learning Environment, the effort use is minimal and some researchers even describe the desirable usage of the system as free from effort (Davis, 1989). PEOU has a direct impact on the second variable that is *perceived usefulness*. The PEOU together with the *Perceived Usefulness* of the SMART Learning Environment is determining in ensuring the eventual *attitude towards use*, *behavioural intention to use* and *actual use.* The *Perceived Ease of Use* of the SMART Learning Environment was examined from two perspectives or viewpoints; the user interface promoting easy use and the SMART Learning Environment as a whole being easy to use. In both situations, positive and encouraging feedback was collected. 77.78% of the respondents either agreed or strongly agreed that the user interfaces of the SMART Learning Environment promote easy use. 84.13% of the respondents agreed or strongly agreed that the SMART Learning Environment is easy to use.

5.2.4 Section D: Perceived Usefulness of the SMART Learning Environment

Section D depicts the 'Perceived Usefulness' of the SMART Learning Environment.

Table 5. 10: Perceived Usefulness of the SMART Learning Environment

	1	2	3	4	5	Total
Statement	**Strongly Disa-gree**	**Disa-gree**	**Not Sure**	**Agree**	**Strongly Agree**	
1. The SMART Learning Environment is effective in providing personalised learning materials.	1 (1.59%)	2 (3.17%)	5 (7.94%)	45 (71.43%)	10 (15.87%)	63 (100%)
2. The SMART Learning Environment is correct in its operations.	1 (1.59%)	1 (1.59%)	4 (6.35%)	41 (65.08%)	16 (25.40%)	63 (100%)

Discussions

Perceived Usefulness, one of the constructs of the Technology Acceptance Model can be seen, as the degree to which a user believes that the usage of the SMART Learning Environment (SLE) would enhance his or her job performance. This construct, in this particular context, was examined from two viewpoints or perspectives. Perceptions that were collected are firstly, whether the SMART Learning Environment (SLE) is effective in providing personalised learning materials and secondly, whether the SLE is correct in its operations. 87.30% of the respondents either agreed or strongly agreed that the SMART Learning Environment is effective in providing personalised learning materials and 90.48% of the respondents found that the SMART Learning Environment is correct in its operations. These two viewpoints are very helpful in establishing the perceived usefulness of the SLE and the results collected are very encouraging.

5.2.5 Section E: Attitude towards Using the SMART Learning Environment

This section shows the results collected as far as the attitude towards using the SMART Learning Environment is concerned.

Table 5. 11: Attitude towards Using the SMART Learning Environment

	1	2	3	4	5	Total
Statement	**Strongly Disagree**	**Disagree**	**Not Sure**	**Agree**	**Strongly Agree**	
1. The SMART Learning Environment offers a motivating and engaging learner experience.	1 (1.59%)	1 (1.59%)	3 (4.76%)	44 (69.84%)	14 (22.22%)	63 (100%)
2. The SMART Learning Environment provides a better learning experience as compared to existing methods of training.	1 (1.59%)	1 (1.59%)	4 (6.35%)	38 (60.32%)	19 (30.16%)	63 (100%)

Discussions

The *Attitude towards using the SMART Learning Environment* (SLE) was gauged by looking at two viewpoints. In the first instance, the researcher tried to figure out whether the SLE offered a motivating and engaging learning experience. Then the researcher collected data to try to understand whether the SLE provided a better learning experience as compared to existing methods of training in the respective workplace of the Cybersecurity professionals. 92.06% of the respondents mentioned that the SLE offered a motivating and engaging learning experience. As far as comparing the SLE with existing methods of training in the workplace of the professionals, 90.48% highlighted that the SLE offered a better learning experience.

5.2.6 Section F: Intention to Use the SMART Learning Environment

Section F presents the results about the intention of the sample surveyed to eventually use the SMART Learning Environment.

Table 5. 12: Intention to Use the SMART Learning Environment

	1	**2**	**3**	**4**	**5**	**Total**
Statement	**Strongly Disa-gree**	**Disa-gree**	**Not Sure**	**Agree**	**Strongly Agree**	
1. The SMART Learning Environment can be used for the training of Cybersecurity Professionals in Mauritius.	1 (1.59%)	1 (1.59%)	3 (4.76%)	42 (66.67%)	16 (25.40%)	63 (100%)
2. The SMART Learning Environment can be used for the training of ICT Professionals in other areas such as Networking and Software Engineering	1 (1.59%)	1 (1.59%)	4 (6.35%)	43 (68.25%)	14 (22.22%)	63 (100%)

Discussions

Data collected in this section helped the researcher understand the *intention to use* the SMART Learning Environment (SLE). This has been determined by analysing the data from two different viewpoints. The first one was to determine whether the SLE can be used for the training of Cybersecurity professionals in Mauritius. 92.07% of the respondents believed that the SLE could be used for this purpose. Another viewpoint that was considered was whether the SLE could be used to train ICT professionals in other areas (such as Networking and Software Engineering) which are in high demand in Mauritius. 90.47% of the respondents either agreed or strongly agreed that this can be the case.

5.2.7 Section G: Further Improvements

Results from the survey questionnaires concerning section G are compiled in the table 5.13 below. For the sake of simplicity, only the most relevant ones are listed.

Table 5. 13: Further Improvements

1	'Gamification can bring an additional aspect of engagement and motivation. It would be interesting if the exercises to be tackled could embrace this concept of gamification'.
2	'A mobile version of the SMART Learning Environment could provide ubiquitous learning and ensure that the learner is learning during any free time available'.
3	'It might be interesting to find ways and means that would encourage learners to learn collaboratively besides learning individually'.
4	'Badges could be awarded once the learner has crossed a certain level or achieved a specific mile-stone'.
5	'Voice-enabled commands/instructions and text-to-speech could prove to be helpful'.
6	'Eye-tracking can be used to study the learner's visual behaviour and through gaze metrics, the learn-ing experience can be evaluated'.
7	'Providing the learner with some kind of embedded electronic notebook within the platform where certain key concepts or information can be noted down'.
8	'A forum space where certain learning experiences can be shared'.

5.3 Further Statistical Analysis

5.3.1 Further interpretation for Research Objective 2 (RO2).

Investigating the effect of Gender on RO2

The statistical analysis presented earlier in this chapter already gives a clear indication of the perception of the respondents in response to RO2 (responses collected for Question B4 in Survey Questionnaire – 'Current techniques used for continuous learning in your company are effective.'). This section unveils further interesting interpretations obtained from the data collected. In response to Research Objective 2 (RO2), 'Explore the effectiveness of the current learning methodologies in bridging the training needs of ICT Professionals in Mauritius', it was seen that 79.37% of the respondents claimed that the current techniques available for the training of Cybersecurity professionals in Mauritius are not effective. Deep diving into the data collected, the researcher wanted to examine whether the results were differentiated by gender for RO2. In other words, the researcher wanted to see whether male or female respondents had the same perception towards this research objective. To achieve this, cross-tabulation through the use of Pivot Tables, was done. Pivot tables proved to be very useful in re-organising the data obtained. The results are shown in Figure 5.1 below and were expressed as a percentage to consider the different number of male and female respondents.

Count of B4	Column Labels		
Row Labels	**Female**	**Male**	**Grand Total**
Strongly Disagree	18.5%	27.8%	23.8%
Disagree	63.0%	50.0%	55.6%
Not Sure	7.4%	16.7%	12.7%
Agree	7.4%	5.6%	6.3%
Strongly Agree	3.7%	0.0%	1.6%
Grand Total	**100.0%**	**100.0%**	**100.0%**

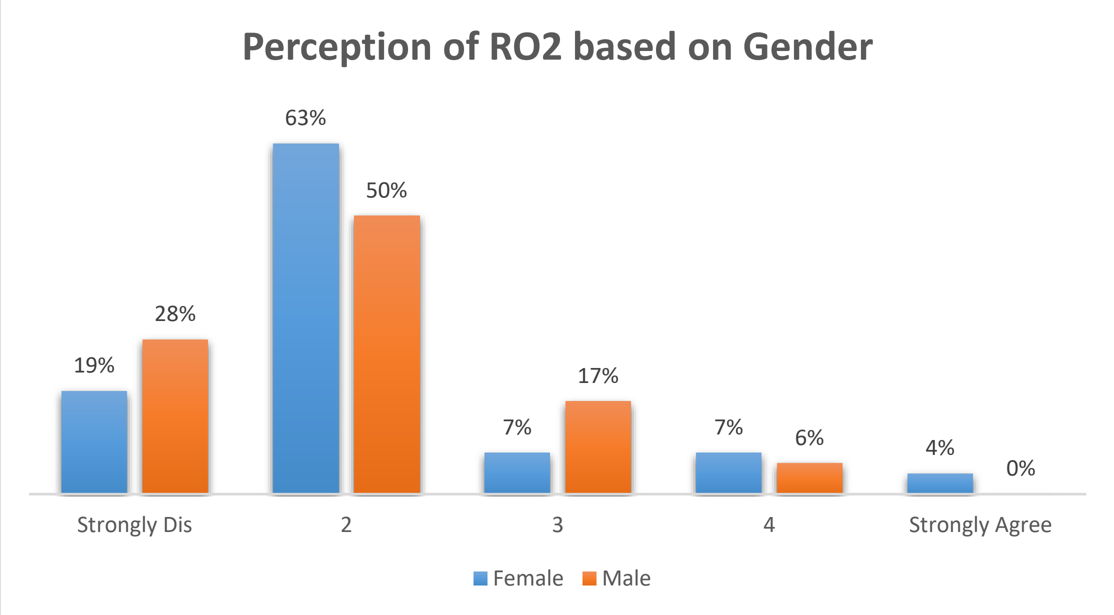


Figure 5. 1: Pivot Tables to investigate the effect of Gender

From data obtained, it can be said that males and females had more or less the same perception as far whether current techniques for continuous learning in their company are effective. 82% of female respondents either strongly disagreed or disagreed that current learning methodologies were effective in bridging the training needs of Cybersecurity professionals in Mauritius. On the other hand, 78% of male respondents either strongly disagreed or disagreed that current learning methodologies where effective in responding to the training needs of Cybersecurity professionals in Mauritius.

Investigating the effect of Job Specification on RO2

Though 79.37% of the respondents claimed that the current techniques available for the training of Cybersecurity professionals in Mauritius are not effective, the researcher wanted to investigate whether the different job specifications of the respondents had any effect on the answers obtained. The different job specifications of the respondents included Information Security Officer, Information Security Analyst, Information Security Consultant, Chief

Information Security Officer and Others (job specifications that did not include the first four classifications). To achieve this, a single factor Analysis of Variance (ANOVA) test was done. The ANOVA test helps to demonstrate whether there is any statistically significant differences between the means of the five groups mentioned above. These five groups correspond to the five job specifications mentioned above. The results of the ANOVA test is shown in Figure 5.2 below.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Information Security Officer	24	44	1.833333	0.405797
Information Security Analyst	20	45	2.25	1.039474
Information Security Consultant	11	21	1.909091	0.290909
Chief Information Security Officer	3	10	3.333333	4.333333
Others	5	10	2	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7.086941	4	1.771735	2.527372	0.050238	2.530694
Within Groups	40.65909	58	0.701019			
Total	47.74603	62				

Figure 5. 2: ANOVA Test

To determine whether the differences between the means are statistically significant, the p-value obtained was compared to the level of significance to assess the null hypothesis. The null hypothesis states that the population means are all equal. The level of agreement for responses obtained from Section B4 of the Survey Questionnaire differs across the job specifications at the 5% level of significance. It can be observed that the p-value for this test is 0.05. Since p-value ≤ 0.05 (to 2 dp), it can be said that the null hypothesis can be rejected and that the means are statistically significant. This implies that job specification has a significant impact on the level of agreement for this specific question. This question was about whether existing techniques for continuous learning are effective. It can be deduced that these Information Security Officers, being rather young with less years of experience, view the current techniques of up-skilling as being highly ineffective. This piece of information is interesting in the sense that these young Cybersecurity professionals who have just started their career as Cybersecurity professionals and who need to be provided the adequate training so as to remain competitive, view the actual techniques of training as highly ineffective. Indeed it is this group of professionals who require the most training and up-skilling so as to aspire to become competitive professionals and eventually progress in their respective fields. On the other hand, it is seen that 'Chief Information Security Officer' is the group of Cybersecurity professionals who view the current learning techniques are being more effective. This can be accounted to the fact that these persons very often are at a managerial position and have themselves set in place certain training mechanisms for the up-skilling of Cybersecurity professionals. It is also to be noted also that the number of respondents from this group of 'Chief Information Security Officer' is very small.

5.3.2 Applying Structural Equation Modeling to Technology Acceptance Model (TAM)

Previous literature about Technology Acceptance Model is diverse and varied. A number of researchers are continuing to do research on TAM in a learning and educational context (Scherer et al., 2018; Hsieh, 2020; Shen and Ho, 2020; Faustino and Simões, 2020). One area where the researcher believes that there can be a contribution as far as TAM is concerned is the use of advanced statistical methods to investigate the significance of the constructs of the TAM model in the context of this research. The TAM has been discussed in much depth in Section 3.5 of this thesis. A diagram to recap the constructs used can prove to be handy and is shown again in Figure 5.3

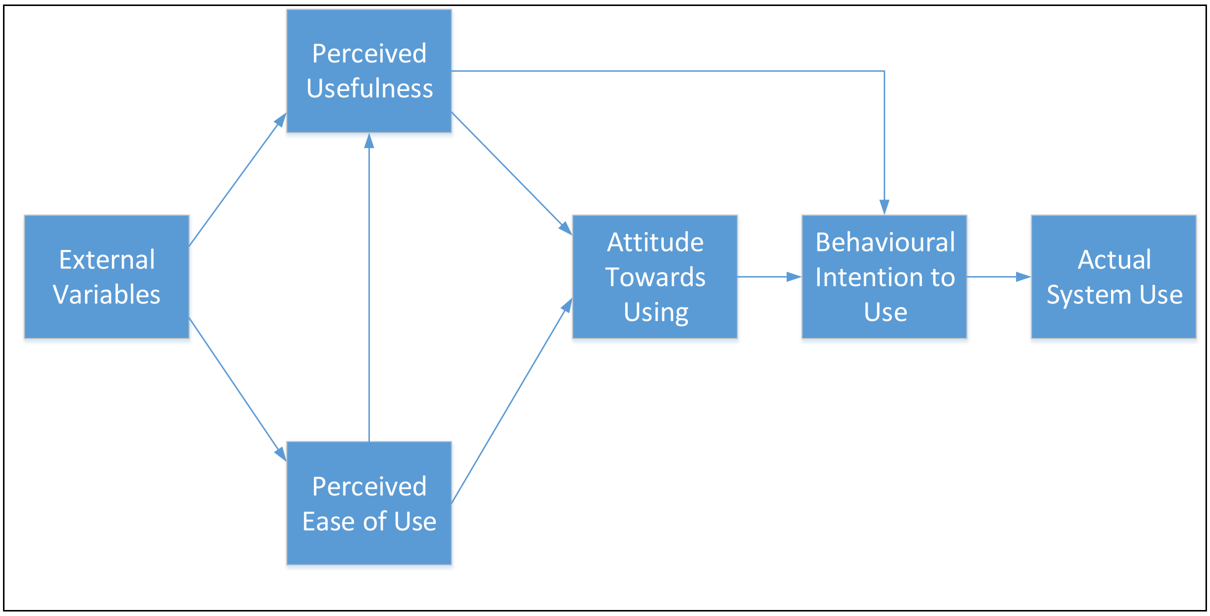


Figure 5. 3: Technology Acceptance Model

The researcher has been experimenting with a number of statistical approaches and techniques but one of them, namely, Structural Equation Modeling (SEM) proved to be very much applicable in this context. This was performed using R, which is basically a free software for statistical computing, programming and graphics. R is commonly used among researchers, statisticians and data analysts to retrieve, analyse, visualise and to present data. In this context, R proved to be more useful than Microsoft Excel.

5.3.2.1 Structural Equation Modeling (SEM)

Structural Equation Modeling (SEM) is a multivariate statistical analysis technique commonly used to analyse structural relationships (StatisticsSolutions, 2020). Its combination of factor analysis and multiple regression analysis makes it suitable to analyse the structural relationship present in the Technology Acceptance Model. A Structural Model can be seen as the theory that shows how constructs are related to each other. In the case of TAM, the constructs that are present are Perceived Ease of Use, Perceived Usefulness, Attitude Towards Using, Behavioural Intention to Use and with Actual System Use being the end-point. External variables can influence the constructs of Perceived Ease of Use and Perceived Usefulness. These external variables when applied to an e-learning context can be in the form of Computer Anxiety, Enjoyment, Subjective Norms, Experience, Self-Efficacy (Abdullah and Ward, 2016). However, a study of these external variables is outside the scope of this research. The Perceived Ease of Use is obtained from Section C of the Survey Questionnaire by computing the mean of the answers obtained from the two questions of this section. Likewise, the Perceived Usefulness is obtained from Section D of the Survey Questionnaire. The Attitude Towards Using is obtained from Section E and the Intention to Use obtained from Section F of the Survey Questionnaire. This is summarised in Table 5.14

Table 5. 14: Constructs of the TAM and Corresponding Section of Survey Questionnaire

Constructs	Corresponding Section of the Survey Questionnaire
Perceived Ease of Use	C
Perceived Usefulness	D
Attitude Towards Using	E
Intention to Use	F

To be able to use R for statistical modelling of SEM, installation of the following packages as listed in Figure 5.4 is essential. *Lavaan*, an acronym for latent variable analysis is an interesting package that allows for the exploration, estimation and understanding of a wide family of latent variables. *SemPlot* allows for the creation of graphical model representations commonly known as path diagrams.

```
install.packages("sem")

install.packages("lavaan")

install.packages("semPlot")
```

Figure 5. 4: Packages in R

Some of the code snippets in R is shown in Figure 5.5

```
setwd("C:/Users/user1/Documents/University/Research/Sungkur")
data<-read.csv("data.csv",header=T)
library(sem)
library(lavaan)
library(semPlot)
data.cor<-cor(data)
sd.cor<-c(sd(data[,1]),sd(data[,2]),sd(data[,3]),sd(data[,4]))
data.cov<-cor2cov(data.cor,sd.cor)
attach(data)
model='
Att..Towards.Using=~Intention.to.Use
```

```
Att..Towards.Using~Perc..Ease.of.Use + Perc..Usefulness
Intention.to.Use~Perc..Usefulness
'
model.fit<-sem(model, sample.cov=data.cov,sample.nobs=length(data[,1]))
summary(model.fit,rsquare=TRUE,standardized=TRUE,fit.measures=TRUE)
parameterestimates(model.fit,standardized=TRUE)
fitted(model.fit)
residuals(model.fit)
fitmeasures(model.fit)
modificationindices(model.fit,sort.=TRUE)
semPaths(model.fit,whatLabels="std",layout="tree")
```

Figure 5. 5: Code Snippets in R

The results obtained from the Structural Equation Modeling is shown in Figure 5.6

```
> summary(model.fit,rsquare=TRUE,standardized=TRUE,fit.measures=TRU
lavaan 0.6-5 ended normally after 32 iterations

  Estimator                                         ML
  Optimization method                           NLMINB
  Number of free parameters                          4

  Number of observations                            63

Model Test User Model:

  Test statistic                                    NA
  Degrees of freedom                                -1
  P-value (Unknown)                                 NA

User Model versus Baseline Model:

  Comparative Fit Index (CFI)                       NA
  Tucker-Lewis Index (TLI)                          NA

Loglikelihood and Information Criteria:

  Loglikelihood user model (H0)               -106.810
  Loglikelihood unrestricted model (H1)       -106.810

  Akaike (AIC)                                 221.620
  Bayesian (BIC)                               230.192
  Sample-size adjusted Bayesian (BIC)          217.605

Root Mean Square Error of Approximation:

  RMSEA                                             NA
  90 Percent confidence interval - lower            NA
  90 Percent confidence interval - upper            NA
  P-value RMSEA <= 0.05                             NA

Standardized Root Mean Square Residual:
```

Figure 5. 6: Results from SEM – part 1

```
Standardized Root Mean Square Residual:

  SRMR                                           0.000

Parameter Estimates:

  Information                                 Expected
  Information saturated (h1) model          Structured
  Standard errors                             Standard

Latent Variables:
                        Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
  Att..Towards.Using =~
    Intention.t.Us         1.000                               0.415    0.600

Regressions:
                       Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
  Att..Towards.Using ~
    Perc..Eas.f.Us        0.016       NA                      0.038    0.032
    Perc..Useflnss        0.459       NA                      1.107    0.760
  Intention.to.Use ~
    Perc..Useflnss        0.459       NA                      0.459    0.456

Variances:
                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
   .Intention.t.Us    0.000                               0.000    0.000
   .Att..Twrds.Usn    0.065       NA                      0.380    0.380

R-Square:
                   Estimate
    Intention.t.Us    1.000
    Att..Twrds.Usn    0.620

> parameterestimates(model.fit,standardized=TRUE)
                 lhs op              rhs   est se  z pvalue ci.lower ci.upper
1 Att..Towards.Using =~  Intention.to.Use 1.000  0 NA     NA    1.000    1.000
2 Att..Towards.Using  ~ Perc..Ease.of.Use 0.016 NA NA     NA       NA       NA
```

Figure 5. 7: Results from SEM – part 2

```
> parameterestimates(model.fit,standardized=TRUE)
                 lhs op                 rhs   est se  z pvalue ci.lower ci.upper
1 Att..Towards.Using =~    Intention.to.Use 1.000  0 NA     NA    1.000    1.000
2 Att..Towards.Using  ~   Perc..Ease.of.Use 0.016 NA NA     NA       NA       NA
3 Att..Towards.Using  ~    Perc..Usefulness 0.459 NA NA     NA       NA       NA
4   Intention.to.Use  ~    Perc..Usefulness 0.459 NA NA     NA       NA       NA
5   Intention.to.Use ~~    Intention.to.Use 0.000  0 NA     NA    0.000    0.000
6 Att..Towards.Using ~~ Att..Towards.Using 0.065 NA NA     NA       NA       NA
7  Perc..Ease.of.Use ~~   Perc..Ease.of.Use 0.712  0 NA     NA    0.712    0.712
8  Perc..Ease.of.Use ~~    Perc..Usefulness 0.494  0 NA     NA    0.494    0.494
9   Perc..Usefulness ~~    Perc..Usefulness 0.471  0 NA     NA    0.471    0.471
  std.lv std.all std.nox
1  0.415   0.600   0.600
2  0.038   0.032   0.038
3  1.107   0.760   1.107
4  0.459   0.456   0.665
5  0.000   0.000   0.000
6  0.380   0.380   0.380
7  0.712   1.000   0.712
8  0.494   0.853   0.494
9  0.471   1.000   0.471
> fitted(model.fit)
$cov
                  Int..U P..E.. Prc..U
Intention.to.Use  0.477
Perc..Ease.of.Use 0.465  0.712
Perc..Usefulness  0.440  0.494  0.471

> residuals(model.fit)
$type
[1] "raw"

$cov
                  Int..U P..E.. Prc..U
Intention.to.Use  0
Perc..Ease.of.Use 0      0
Perc..Usefulness  0      0      0
```

Figure 5. 8: Results from SEM – part 3

```
> residuals(model.fit)
$type
[1] "raw"

$cov
                   Int..U P..E.. Prc..U
Intention.to.Use   0
Perc..Ease.of.Use  0      0
Perc..Usefulness   0      0      0

> fitmeasures(model.fit)
               npar                fmin               chisq                  df
              4.000               0.000                  NA              -1.000
             pvalue                 cfi                 tli                nnfi
                 NA                  NA                  NA                  NA
                rfi                 nfi                pnfi                 ifi
                 NA                  NA                  NA                  NA
                rni                logl   unrestricted.logl                 aic
                 NA            -106.810            -106.810             221.620
                bic              ntotal                bic2               rmsea
            230.192              63.000             217.605                  NA
     rmsea.ci.lower      rmsea.ci.upper        rmsea.pvalue                 rmr
                 NA                  NA                  NA               0.000
         rmr_nomean                srmr        srmr_bentler srmr_bentler_nomean
              0.000               0.000               0.000               0.000
               crmr         crmr_nomean          srmr_mplus   srmr_mplus_nomean
              0.000               0.000               0.000               0.000
              cn_05               cn_01                 gfi                agfi
                NaN                 NaN               1.000               1.000
               pgfi                 mfi                ecvi
             -0.167                  NA                  NA
Warning messages:
1: In qchisq(p = 0.95, df = df) : NaNs produced
2: In qchisq(p = 0.99, df = df) : NaNs produced
> modificationindices(model.fit,sort.=TRUE)
Error in modificationindices(model.fit, sort. = TRUE) :
  lavaan ERROR: could not compute modification indices; information matrix is singular
> semPaths(model.fit,whatLabels="std",layout="tree")
```

Figure 5. 9: Results from SEM – part 4

The model generated by R together with the corresponding weights is shown in Figure 5.10. This figure has been redrawn and shown in Figure 5.11 due to the poor quality of the figure generated by R and the use of abbreviations used by R to denote the constructs of TAM.

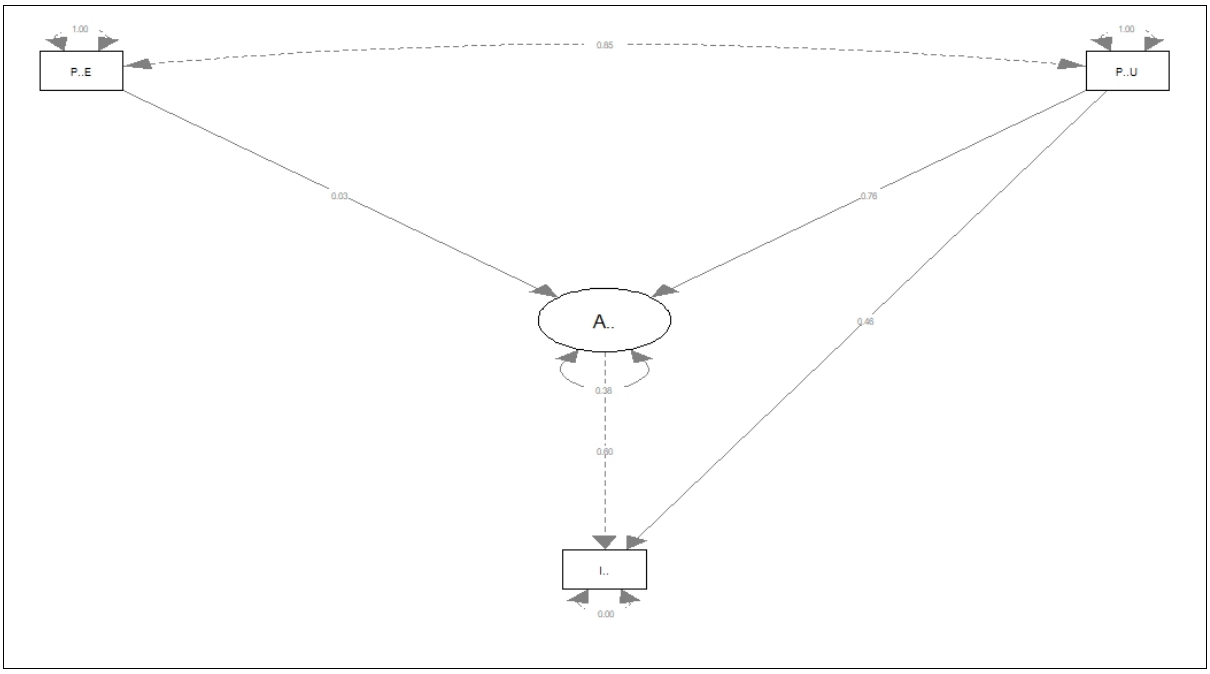


Figure 5. 10: Results from SEM – part 5

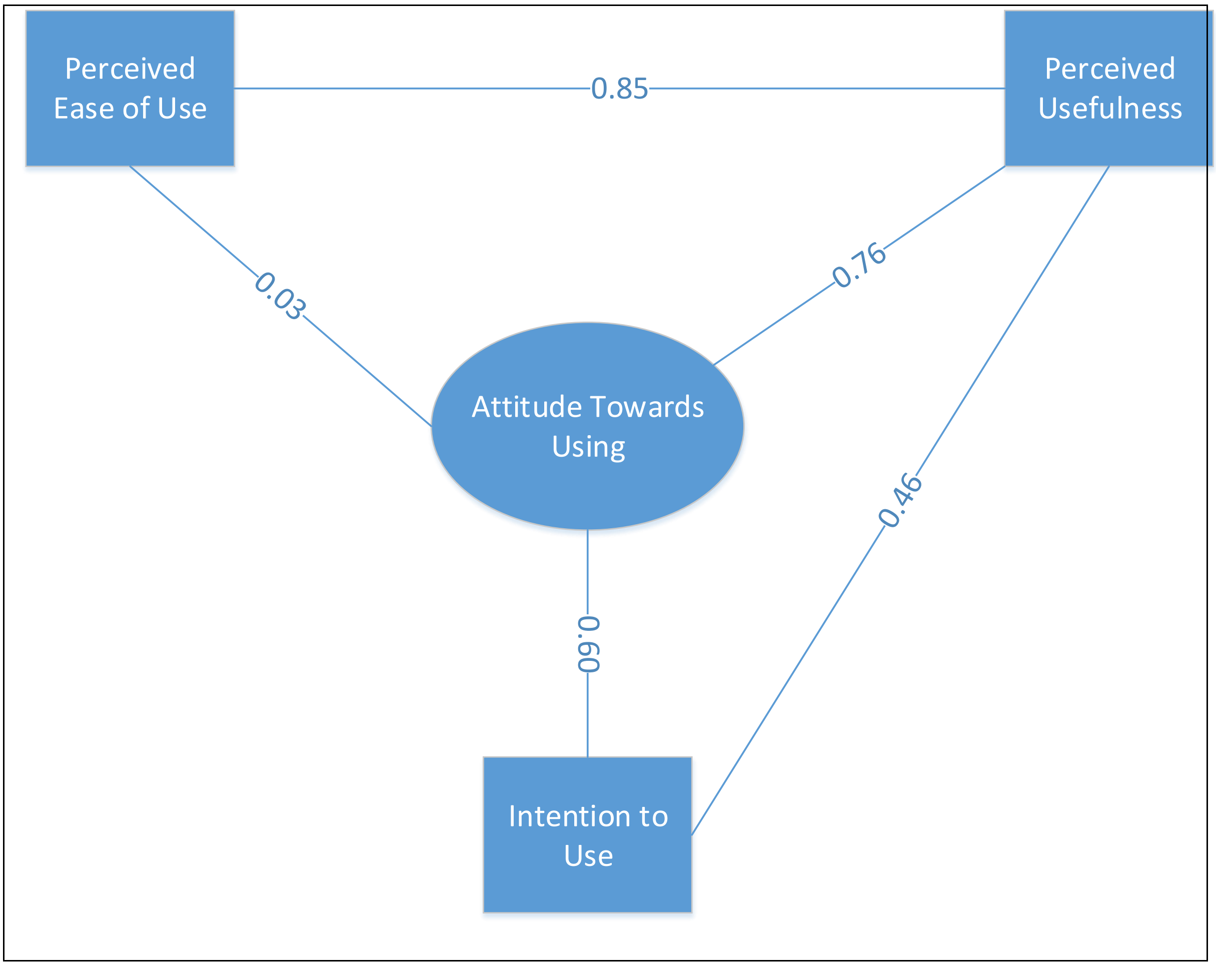


Figure 5. 11: Redrawn SEM Model obtained from R

The constructs of Perceived Ease of Use and Perceived Usefulness are often considered at the two most important constructs in the Technology Acceptance Model (Chen et al., 2013). This is because the user's acceptance or rejection of the proposed system is mainly guided by these two constructs. It is seen from the model generated that there is a strong relationship between the two constructs of Perceived Ease of Use and Perceived Usefulness. The model generated also implies a strong relationship between Perceived Usefulness and Attitude Towards Using. On the other hand, it is observed that there is a weak relationship between Perceived Ease of Use and Attitude Towards Using. This can be attributed to the fact that the audience targeted is mostly Cybersecurity Professionals with a strong background of using computerised systems and for them, the usefulness of the proposed system is more important and that the ease of use of the system becomes more or less obvious.

5.4 Chapter Summary

Chapter 5 presented the results of the Survey Questionnaire collected from the sample of Cybersecurity professionals. The data collected during this exercise strengthened and triangulated the information obtained during the Desk Studies and Expert Reference Group Discussion carried out earlier. The major findings from the survey questionnaire consolidates the preliminary opinion that Cybersecurity is a rather new but fast-evolving sector in Mauritius, which is however not fully supported in terms of adequate training. Indeed, the respondents pointed out that contemporary means of training in their respective companies are not very efficient and effective. The respondents were presented with the SMART Learning Environment which was positively accepted. This chapter ends with some further statistical analysis to deep dive into data collected and shed light on certain observations that are not apparent at a first glance. Chapter 6 that follows concludes and critically analyses the research undertaken with special focus on the researcher's contribution to the domain.

CHAPTER SIX: CONCLUSION

6.1 Introduction

Chapter 6 is the final chapter of this thesis. It summarises the research undertaken, presents the major findings and discusses the implications of this study. The researcher's contribution to the domain is also highlighted. This chapter also highlights how progress in technology has helped address a problem of national interest. The chapter also reveals the limitations of this research and also suggests possible opportunities for further investigation. Indeed, the world of computing is a highly dynamic and ever-evolving one. For sure, in the future, other techniques, approaches and technologies can be used to advance the findings of this study.

6.2 Summary of the study

Chapter 1 introduces the problem under investigation, gives an overview of the research questions to be tackled and stresses on the importance of the research problem for the Republic of Mauritius. The chapter also presents a research blueprint for the study.

Chapter 2 presented the literature review and background to the study. The concepts of Technology Enhance Learning (TEL), Artificial Intelligence, Machine Learning, Neural Network, Deep Learning, Agent Based Technology, Educational Data Mining, Learning Analytics, Sensor Technologies and IoT are thoroughly discussed. The chapter ends with concepts of pedagogy, learning styles and highlights the importance of lifelong learning.

In Chapter 3, Design Science Research Methodology (DSRM), Activity Theory, Bloom's Taxonomy and the Technology Acceptance Model (TAM) are discussed. This chapter also presents the SMART Learning Model and thoroughly discusses concepts of Research Design and ends with a discussion on Ethical Considerations.

Chapter 4 discusses the DSRM process. The development of the SMART Learning Environment was clearly mapped to the DSRM stages through a rigorous process of design-evaluate-redesign.

Chapter 5 presents the results of the research. The SMART Learning Environment presented to the sample of Cybersecurity Professionals was eventually analysed from the constructs of the Technology Acceptance Model (TAM). This is followed by statistical analysis which helped the researcher deep dive into the results obtained and draw conclusions. The chapter ends with a discussion of the findings.

Chapter 6 is the last chapter of this thesis and concludes this research.

6.3 Research Questions revisited

The main research question for this study was "How can the training needs of Cybersecurity Professionals in Mauritius be addressed through the use of a SMART Learning Environment providing personalisation of learning content?" This question resulted in the following research objectives as listed in table 6.1 below. The table also contains the different sections of the thesis where the research objectives are discussed in depth.

Table 6. 1: Research Objectives and sections of thesis that highlights the answers

Research Objective	Description	Answered Through or Source of Information / Sections of Thesis
(RO1)	Explore the training needs of Cybersecurity professionals in the ICT Sector of Mauritius	Online Desktop Research (Section 1.8, Section 2.13), Government Published Data (Annexure A) and Expert Reference Group Discussion (Section 3.8, Section 3.14, Annexure C, Annexure H).
(RO2)	Explore the effectiveness of the current learning methodologies in bridging the training needs of ICT Professionals in Mauritius	Online Desktop Research (Section 2.13), Government Published Data (Section 1.3), Expert Reference Group Discussion (Section 3.8, Section 3.14, Annexure C, Annexure H) and Survey Questionnaires (Section 5.2.2).

(RO3)	Analyse how SMART Learning Environments providing personalisation of Learning Contents operate.	Online Desktop Research - Conference and Journal Papers (Section 2.6, Section 2.7, Section 2.8, Section 2.9, Section 2.10)
(RO4)	Analyse the different Intelligent Techniques available for implementing SMART Learning Environments	Online Desktop Research - Conference and Journal Papers (Section 2.11)
(RO5)	Design, Develop and Evaluate a SMART Learning Environment	Design Science Research Methodology (Chapter 4)
(R06)	Assess the effectiveness of the SMART Learning Environment in providing Continuous Learning for Cybersecurity professionals in the ICT Sector of Mauritius as compared to traditional Technology Enhanced Learning	Survey Questionnaires (Section 5.1), Analysis and findings of study (Section 5.2, Section 5.3)

Research Objective 1 (RO1): Explore the training needs of Cybersecurity professionals in the ICT Sector of Mauritius.

RO1 was thoroughly discussed in the sections mentioned above in Table 6.1. From the different studies carried out, it can be concluded that Cybersecurity is a highly dynamic area and Cybersecurity professionals regularly need to be trained. Common job specifications in this area include Information Security Officer, Information Security Analyst, Information Security Consultant and Chief Information Security Officer. It has been observed from data collected that for a Cybersecurity Professional progress professionally, certifications is a must. It has been seen that in certain situations, certain employers require that these professionals get certified for them to either be confirmed in their post or for them to be transferred from contractual terms to permanent establishment in their respective workplace. Two certifications that are common among Cybersecurity professionals in Mauritius include CompTIA Security+ and Certified Ethical Hacker (CEH). It has also been observed that CISA, CISM and CISSP are important certifications for those who aspire to embrace a managerial position in the field of Cybersecurity. The data collected during the survey carried out reinforces the situation depicted in Figure 1.6, whereby it was established that the minimum qualification to aspire a job in the area of Cybersecurity in Mauritius, is a degree in an IT-related field.

Research Objective 2 (RO2): Explore the effectiveness of the current learning methodologies in bridging the training needs of ICT Professionals in Mauritius.

It is apparent that the learning techniques to up-skill Cybersecurity professionals in Mauritius are not effective. In Mauritius, Cybersecurity professionals opt mostly for online courses. It has been found that the experience generated from these courses are not very engaging and motivating. The respondents claimed that the current techniques available for the training of Cybersecurity professionals in Mauritius are not effective and do not address the individual needs of these professionals.

Research Objective 3 (RO3): Analyse how SMART Learning Environments providing personalisation of Learning Contents operate.

Much of previous work undergone in the area of personalisation of learning content is related to concepts of ubiquitous learning, context-aware e-learning and adaptive learning. The difference between these concepts have been compiled in Section 2.7 and Annexure B.

Research Objective 4 (RO4): Analyse the different Intelligent Techniques available for implementing SMART Learning Environments.

Personalisation of learning content to address the issue of one-size fits-all, is mostly done through the use of Intelligent Techniques. Intelligent Techniques that have been used in previous research works include the use of Artificial Intelligence and Machine Learning through the use of Fuzzy C-Means algorithm, Agent-Based Technology, Genetic-Based Algorithm, Artificial Neural Networks, Decision Trees, Clustering, Bayesian Networks, Hidden Markov Models, Deep Learning, Educational Data Mining and Learning Analytics.

Research Objective 5 (RO5): Design, Develop and Evaluate a SMART Learning Environment.

The Design Science Research Methodology (DSRM) was adopted as the framework for the development of the SMART Learning Environment which was iteratively refined through testing until it was fit for use.

Research Objective 6 (RO6): Assess the effectiveness of the SMART Learning Environment in providing Continuous Learning for Cybersecurity professionals in the ICT Sector of Mauritius as compared to traditional Technology Enhanced Learning.

Quantitative and qualitative data revealed that respondents overwhelmingly agreed or strongly agreed that the SMART Learning Environment proposed offers a motivating and enriching learning experience.

6.4 Primary Research Outcome

Currently, there is a pressing need to re-invent the way training is done for working professionals in the field of Cybersecurity in Mauritius. Indeed, it has been observed that continuous professional development is a must for these professionals since they have to keep pace with the latest development in the highly dynamic cybersecurity field. These professionals have to be trained to become lifelong learners and 21st century learning implies a complete shift in the teaching and learning process. A complete re-engineering of the training process has to be envisaged and this is why this research puts forward a novel approach which personalises the learning experience by considering the prior knowledge and aptitude of the learner.

During the last four decades, several behavioural theories and intentional models have been developed to study user behaviours concerning the adoption of technology. Making predictions on the acceptance of an innovative technology by users is not an easy task. Several theoretical frameworks and models have been discussed and used in this research. These were the Design Science Research Methodology (DSRM), Activity Theory, Bloom's Taxonomy and the Technology Acceptance Model (TAM). Due to the inherent limitations of the models mentioned, the researcher also proposed and evaluated an emergent conceptual model, the SMART Learning model.

The SMART Learning Environment, developed through the DSRM process uses a modular approach. This makes the modification of features easier and offers better maintainability of the system. The SMART Learning Environment is able to determine the initial competency of a learner, evaluate the performance of a learner through a number of tests carried out and eventually establish a learning path for the learner to be able to reach to his/her desired level. The proposed SMART Learning Environment presents a number of interesting features and functionalities, much appreciated by Cybersecurity professionals who have experimented with the system. The ability to personalise the learning contents through the use of 'Intelligent Techniques' such as Artificial Neural Network is interesting and novel. It addresses the problem of 'one-size-fits-all' described by numerous researchers in the area of education and pedagogy. The SMART Learning Environment also offers visualisation features in the form of graphs and charts that are able to show the progress and eventually provide timely feedback to the learner. Learners that are lagging behind are provided with consolidation exercises and materials as identified by the recommendation module so that they are able to reach to the desired level. Important messages can also be sent through the use of notifications.

Besides these, this research also sheds light on the current situation of Cybersecurity professionals operating in Mauritius. ICT being one of the pillars of the Mauritian Economy, having Cybersecurity professionals who are competitive, is critical.

6.5 Implications of the study

The research undertaken has numerous implications for researchers, industry practitioners, the Business Sector and the Government through governmental bodies falling under the aegis of the Ministry of Technology, Communication and Innovation (TCI) of the Republic of Mauritius. From a researcher's perspective, this research has enabled to help further understand the training needs of Cybersecurity professionals in Mauritius, to formulate and evaluate a new emergent conceptual model and to experiment with a novel approach of training through the use of a SMART Learning Environment making use of AI Techniques. It can also be said that this has positively contributed to research in the area of Technology Enhanced Learning, Information Systems and Technology.

From a practitioner's point of view, this research has enabled the Cybersecurity professionals to experience a more engaging, motivating and effective means of training. The results collected from the sample of Cybersecurity Professionals were quite encouraging. The business world is highly competitive and demanding. Cybersecurity Practitioners have to remain abreast of latest technologies, techniques and developments in the area of Cybersecurity. For the Business Sector, training in the form of up-skilling and re-skilling happens in a more effective way, thereby minimising disturbance at work, ensuring productivity and therefore minimising costs. It can also be said that by adapting the learning materials present on the SMART Learning Environment, the system can be modified for the training of other ICT professionals in other areas such as networking and software engineering.

From the Government's (Republic of Mauritius) perspective, it can be said that the research has helped address a problem of national interest. As discussed in section 1.2, 1.3 and 1.8, there is a definite concern with the skills mismatch on one side and on the other side, the growing number of unemployed graduates in areas other than IT. The Universities of the Republic of Mauritius are not able to produce the number of graduates in the field of IT required by the Industry / Business. On the other hand, it is observed that graduates in areas such as Sociology, Marketing, Political Studies, Agriculture, just to name a few, end up being unemployed, even after having secured a degree. This is why, the Government of the Republic of Mauritius is spending much through conversions programmes to the field of IT, sponsored by the HRDC (as discussed in Sections 1.2 and 1.3). This is done with the help of major players in the IT Industry of Mauritius such as Accenture Mauritius, Orange Business Services and Ceridian Mauritius. These companies require specific technical skills from their employees and the SMART Learning Environment put forward in this research can provide definite options for up-skilling and even re-skilling whilst ensuring that that the training needs of their employees are addressed in a motivating, engaging and effective way. In the Government Programme 2020-2024 of the Republic of Mauritius, in the section of 'Education and Skills for the World of Tomorrow' the Government has reiterated that Education and Training be at the core of the Government's inclusiveness agenda. This report also continues by adding that 'as the country enters the next phase of its development, Government will create an environment conducive to learning through modern digital technology and latest best practices' (Government Programme

2020-2024, 2020). This is why it is perceived that this research would be of great interest to the Government of Mauritius and the outcome of this research has been communicated to the Ministry of Technology, Communication and Innovation of the Republic of Mauritius (Annexure J).

The situation depicted in this section is very much in line with Triple Helix Model of Innovation where interactions and cooperation between Academia, Business and the Government is seen as the agent of change that will foster economic and social development. Here in this context of research, it is the provision of adequate training to ensure the competency of the professionals in the field of Cybersecurity by the help of actors in the Triple Helix Model of Innovation that will eventually ensure economic and social development.

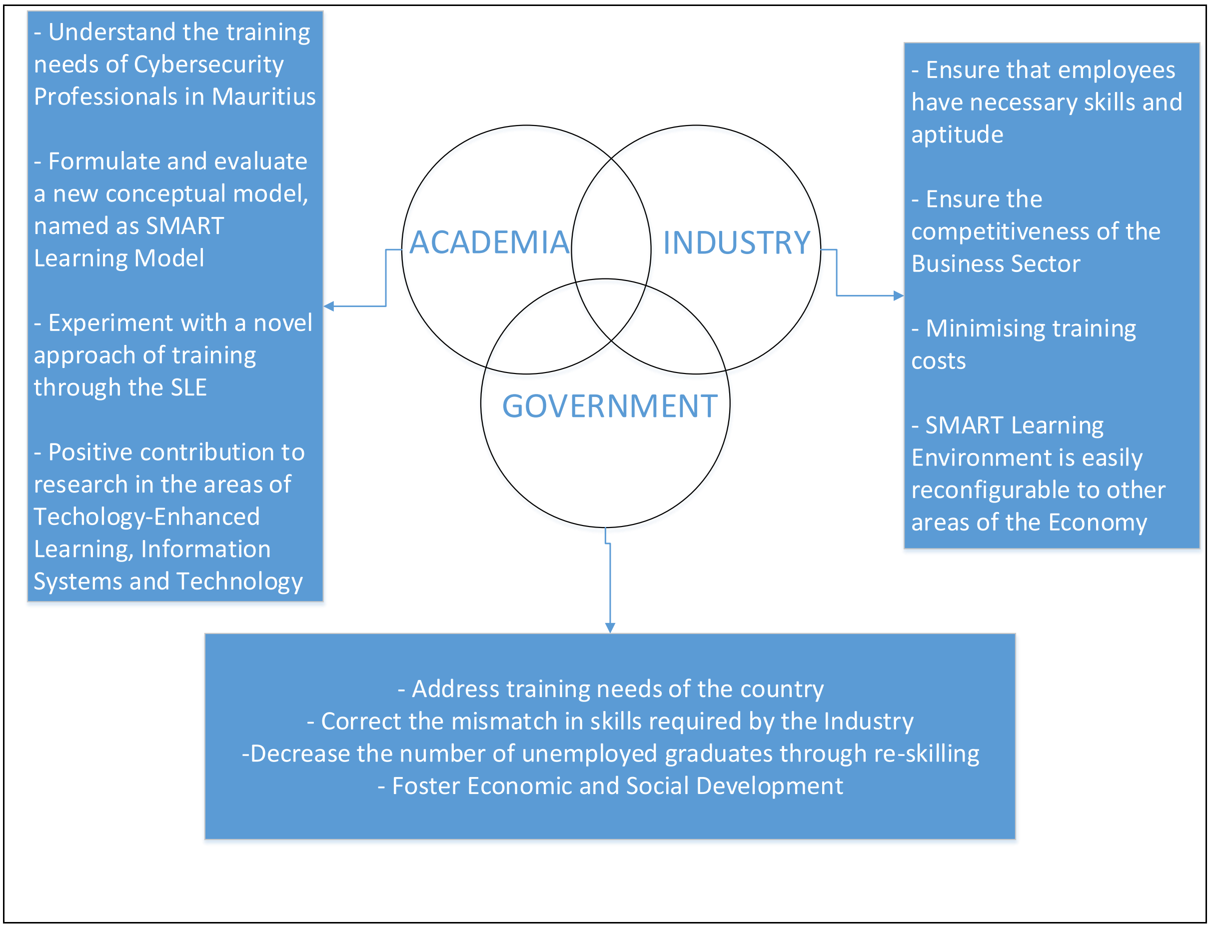


Figure 6. 1: Implications of the study and Triple Helix Model of Innovation

(Source: Researcher's own construction)

6.6 Researcher's contribution to the body of knowledge

The researcher has been contributing to the fore-front of research in a number of ways. The first contribution by the researcher has been in the elaboration of a detailed critical analysis of existing Learning Environments making use of Intelligent Techniques whilst pointing out their strengths and weaknesses. A century's evolution of Technology Enhanced Learning has also been compiled and the way forward has been discussed. Artificial Intelligence and Machine Learning as pillars to develop Intelligent Learning Systems and more specifically SMART Learning Environment have also been discussed.

The second contribution was in the formulation and evaluation of a new conceptual model, called the SMART Learning Model. This served as a lens or paradigm to express the problem situation, provide ways to represent a solution and allow for suggestions to be followed in order to achieve a specific solution. Indeed, the already available theoretical models and frameworks had their inherent limitations and it is only through the formulation of an emergent conceptual model that the research questions could be addressed.

The third contribution involves the design and development of a SMART Learning Environment in the context of training of Cybersecurity Professionals. The requirements of DSRM have also been fulfilled. Previous literature show that Intelligent Learning Systems and SMART Learning Environments have been developed in the past but never in the context of professional development. Previous studies also presented personalised learning where it was observed that there was a problem with the continuity of the learning pathways. The proposed system ensured that the learning pathways and progress are smooth and can easily be visualized. This research also depicted how SMART Learning Environments can be used to address an issue of national importance and gives a more practical insight of how it can be used in a real-life scenario. Again, previous research in the area of Intelligent Learning Systems were mostly restricted to academic scenarios done for research purposes.

Fourthly, this research also helped to further understand the job specifications, daily activities and training needs of Cybersecurity professionals in Mauritius. This can be used to further consolidate existing information published by governmental bodies and the Business Sector.

Last but not least, the researcher has brought together stakeholders from Academia, Industry Practitioners, the Business Sector and the Government of Mauritius to help address an issue of national importance. It is a fact that there are a number of unemployed graduates on the one hand and a shortage of trained IT professionals on the other hand. Unemployment of graduates, who have spent at least three years at University, leads to various economic, social and personal problems. As a senior lecturer in Software and Information Systems at the University of Mauritius, the researcher has been working closely with Industry Practitioners, the Business Sector and the Government of Mauritius to understand the training needs of IT professionals in Mauritius and the Industry needs as far as IT and BPO is concerned. It is a fact that Universities in Mauritius are able to produce only half of the labour force required by IT/BPO Sector in Mauritius. In his attempt to contribute towards reducing this mismatch in skills required by the IT Industry, the researcher has mounted a Master's degree in Business Enterprise Resource Planning (BERP) and another Master's degree in Applied Software Technology (AST) run jointly by Accenture Mauritius and the University of Mauritius and fully sponsored by the Human Resource Development Council (HRDC) of Mauritius. Unemployed graduates in a number of fields are able to follow the two programmes, embark on an internship programme at Accenture Mauritius and eventually be employed by Accenture Mauritius at the end. Up to now, around 150 unemployed graduates have benefited from this conversion programme and with such a SMART Learning Environment, the training can even be more effective and can even reach out to a higher number of unemployed graduates at a more cost-effective way. The SMART Learning Environment can prove to be really helpful in this context since the unemployed graduates come from different backgrounds and have different prior knowledge of IT. For example, an unemployed graduate from the field of Mathematics already have a background of programming and his training needs would be different from an unemployed graduate from the field of Agriculture where programming is not covered. The future plan of the researcher is to be able to mount a Masters in Cybersecurity under the same scheme where a number of unemployed graduates can benefit. This is very much in line with the vision of Government of Mauritius which would want to set up a state of the art regional centre of excellence on Cybersecurity and Cybercrime in Mauritius (Central Informatics Bureau, 2020). The Central Informatics Bureau (CIB) operates under the aegis of the Ministry of Technology, Communication and Innovation (MTCI) in view of providing advisory services in the field of IT to Ministries and Departments of the Republic of Mauritius.

6.7 Limitations of study

This study has been carried out in the context of Cybersecurity professionals in Mauritius. Generalising the outcome of this research to other countries is not envisaged at this stage since the training needs of these professionals might be different. The Literature has also been focusing on research papers written in English. Relevant studies, written in other languages have been omitted and not included in this study

6.8 Recommendations and Future Research

One of the recommendations on this research would be in line with the Triple Helix model of Innovation discussed in section 6.5 above. It is important that Academia, the Government and the Business Sector work together so as to provide a systemic framework so that innovation and knowledge be properly created, disseminated and eventually used. In the context of this research, the contribution and support of Academia, the Business Sector and the Government has to be acknowledged. However, for its wide scale use, it is important that the different stakeholders have this 'shared vision' and that funding opportunities from the Business Sector and the Government are made available so as to scale up the use of the SMART Learning Environment to the whole of the population of Cybersecurity professionals in Mauritius. This would imply having more Cybersecurity-related professional courses on the SMART Learning Environment and having dedicated IT support staff to ensure its availability.

Future work would include the use of Natural Language Processing to analyse the correctness of responses in the form of full sentences and to develop a mobile version of the SMART Learning Environment which thereby enable true Anywhere Anytime Learning. Currently, there is also much research done in the area of eye-tracking, eye gaze, facial expressions, emotion and gesture tracking. These can easily be captured by a webcam on the device and could be used by the SMART Learning Environment to determine certain cognitive features and metrics such as level of attention, emotional engagement, memory retention and cognitive load. Future works can also include the option of multi-language support, training in different environments and modularisation of the SMART Learning Environment to allow for easy add-ons and changes of specific modules.

6.9 Chapter Summary and Conclusion

This chapter concludes this research by providing a summary of the work undertaken. The stated objectives have been achieved. The proposed SMART Learning Environment was successfully implemented and tested by a sample of Cybersecurity Professionals who widely acknowledged that it can positively contribute to bridge the training needs of Cybersecurity Professionals in Mauritius.

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Annexure A – Cybersecurity Professionals in Mauritius

Job Title, Responsibilities, Qualifications and Required Competencies for a CyberSecurity Professional in Mauritius (Source: HRDC, 2017)

Job Title	Mission Responsibilities	Qualifications / Experience	Required Competencies
Information Security Officer	✓ Monitors internal control systems to ensure that appropriate information access levels and security clearances are maintained ✓ Monitors and analyses network security hardware and software (for example, Firewalls, Intrusion Detection Systems) ✓ Assists in drafting Information Security policies and procedures based on international standards e.g. ISO 27001 ✓ Provides support in conducting risk and vulnerability assessments	✓ University Degree in IT related field ✓ Information Security Certifications e.g. CompTIA Security+ ✓ At least 1 year relevant experience in the Information Security field	✓ Interpersonal Relationship ✓ Initiative ✓ Commitment and Collaboration ✓ Analysis and Innovation ✓ Values and Ethics
Information Security Analyst	Responsible for securing information of the organization by designing, implementing, and enforcing security controls, safeguards, policies and procedures Description: ✓ Develops, enforces and performs periodic review of information security policies and procedures ✓ Conducts risk assessments and security audits ✓ Performs network based vulnerability scans and penetration tests	✓ University Degree in IT related field/Computer Security ✓ Information Security Certifications e.g. Certified Ethical Hacker (CEH) or ISO 27001 Implementer/ Auditor or Certified Information	✓ Interpersonal Relationship ✓ Initiative ✓ Commitment and Collaboration ✓ Analysis and Innovation ✓ Values and Ethics

	✓ Monitors, reviews intrusion detection systems/firewall logs; events and patterns ✓ Manages security incidents and evaluates its impact and communicates results to end users and technical staff ✓ Organizes and conducts training for all employees on information security	Security Analyst (CSA) ✓ At least 3 years of experience in information security	
Information Security Consultant	Responsible to manage the IT Security posture of the organisation's business functions and advise management to improve information risk and curtail cyber threats Description: ✓ Advises and assists on information security risk and control matters of the organization ✓ Develops information security roadmaps, strategies and remediation plans ✓ Implements security solutions (infrastructure and/or application) including the design, configuration, development, testing and deployment of security-related technologies ✓ Supports the design, implementation, operation and maintenance of Information Security Management System (For example, ISO/IEC 27001 series standards)	✓ Postgraduate degree in Information Security /Computer Security/Information Technology ✓ At least any one of these Certifications e.g. Certified Ethical Hacker (CEH) or Certified Information Security Auditor (CISA) or Certified Information Security Manager (CISM) or Certified Information Systems Security Professional (CISSP)	✓ Interpersonal Relationship ✓ Initiative ✓ Commitment and Collaboration ✓ Analysis and Innovation ✓ Values and Ethics ✓ Leadership

	✓ Conducts internal information security audits /snapchecks ✓ Manages the implementation of Business Continuity Plans and Disaster Recovery Plans	✓ At least 5 years of experience in information security	
Chief Information Security Officer	Responsible for the organisation's entire security posture, to oversee and coordinate security function of the organisation, including the overall security strategy and security architecture development Description: ✓ Identifies security goals, objectives and metrics consistent with corporate strategic plan ✓ Develops and maintains information security strategies ✓ Advises top management on information security and assurance issues ✓ Establishes an information security and risk management functional capability and framework across the organization ✓ Manages the design, implementation, operation and maintenance of Information Security Management System (such as ISO/IEC 27001, ISO/IEC 22301 series standards)	✓ Postgraduate degree in Information Security/Computer Security/Information Technology ✓ Information Security Certifications e.g. Certified Information Systems Security Professional (CISSP) or Certified Information Security Manager (CISM) ✓ At least 10 years of experience in Information Security and at least 2 years of experience at a managerial position	✓ Interpersonal Relationship ✓ Initiative ✓ Commitment and Collaboration ✓ Analysis and Innovation ✓ Values and Ethics ✓ Leadership

	✓ Ensures that strategic information security and risk guidance provided to third-party suppliers is in accordance with internal frameworks ✓ Monitors, manages and deploys security controls as appropriate to support business needs while minimizing risk		

Annexure B – Discussion Document for Expert Reference Group

Comparison between Context-Aware u-learning, Adaptive Learning and SMART Learning (Source: Adapted from Hwang, 2014)

	SMART Learning	u-learning	Adaptive Learning
Detects and takes into account the real-world contexts	Yes	Yes	No
Situates learners in real-world scenarios	Yes	Yes	No
Adapts learning content for individual learners	Yes	No	Yes
Adapts the learning interface for individual learners	Yes	No	Yes
Adapts learning tasks or objectives for individual learners	Yes	No	No
Provides personalized feedback or guidance	Yes	Yes	Yes
Provides learning guidance or support across disciplines	Yes	No	No
Provides learning guidance or support across contexts (e.g., in classrooms, on school campuses, in the library, and on the street)	Yes	Yes	No
Recommends learning tools or strategies	Yes	No	No
Considers the online learning status of learners	Yes	No	Yes
Considers the real-world learning status of learners	Yes	Yes	No
Facilitates both formal and informal learning	Yes	Yes	No
Takes multiple personal factors and environmental factors (e.g., learning needs, preferences, schedules and real-world contexts) into account	Yes	No	No
Interacts with users via multiple channels (e.g., smartphones, Google Glass, or other ubiquitous computing devices)	Yes	Yes	No
Provides support to learners with “in advance adaptation” across real and virtual contexts	Yes	No	No
Provides support to learners with “on the run adaptation” across real and virtual contexts	Yes	No	No

Annexure C – Discussion Document for Expert Reference Group

Proposed SMART Learning Environment to bridge the Training Needs of Cybersecurity Professionals in Mauritius

Kindly provide your expert opinion on the SMART Learning Environment and its intended use in this study by answering the questions below:

1. Is the proposed SMART Learning Environment reflective of the study concepts and does it provide realistic opportunities for:

- Expressing the problem situation
- Bridging the gap of existing learning methodologies in the training of Cybersecurity Professionals in Mauritius
- Providing constructs for creating a solution to the problem
- Providing the researcher with conceptual tools to suggest activities to achieve the solutions mentioned above.

2. What additional technological concepts/features can be suggested to better align the use of SMART Learning Environments for up-skilling and re-skilling of Cybersecurity professionals in Mauritius.

3. Comment on other factors that are important for the proper use of SMART Learning Environments in work / business environments.

Annexure D – Pre-Test Questionnaire for evaluation of the proposed SMART Learning Environment

Title: Bridging the Training Needs of Cybersecurity Professionals in Mauritius through the use of SMART Learning Environments

Preamble

Thank you for volunteering to participate in this research. A new framework has been developed to address the training needs of ICT Professionals in Mauritius. You have been chosen to give an initial feedback on the SMART Learning Environment and your feedback will be used to further refine the software through an iterative process until it is ready to be tested by a sample of Cybersecurity professionals in Mauritius.

INTERVIEW QUESTIONS: Guided questions for a Pre-test sample of Cybersecurity Professionals in Mauritius

SECTION A: EASE OF USE

1. Researcher: Describe your experience with the ease of use of the SMART Learning Environment

Respondent: ……………………

2. Researcher: What changes would you make to improve the ease of use?

Respondent: ……………………

3. Researcher: Comment on your satisfaction with the user interface. Does it promote easy use?

Respondent: ……………………

SECTION B: FUNCTIONALITY AND CAPABILITY OF THE SMART Learning Environment

1. Researcher: Discuss your satisfaction with the effectiveness of the SMART Learning Environment in providing personalised and adapted learning materials for a more effective learning experience as opposed to existing methods for continuous learning.

Respondent: ……………………

2. Researcher: Comment on the correctness of the SMART Learning Environment

Respondent: ……………………

3. Researcher: Comment on possible improvements to the proposed SMART Learning Environment

Respondent: ……………………

Annexure E – Survey Questionnaire for evaluation of the proposed SMART Learning Environment

Title: Bridging the Training Needs of Cybersecurity Professionals in Mauritius through the use of SMART Learning Environments

Preamble

Thank you for volunteering to participate in this research. A new SMART Learning Environment has been developed to address the training needs of Cybersecurity Professionals in Mauritius. It will take approximately 10 minutes to answer the questions that follow.

The purpose of this questionnaire is to therefore elicit the views of a sample of Cybersecurity Professionals in Mauritius on the extent to which the new learning environment is able to meet their training needs and ensure their constant up-skilling and re-skilling.

It is essential that you answer the questions as honestly as possible. Your responses will be treated confidentially. Kindly contact R. K. Sungkur via r.sungkur@uom.ac.mu for any clarification.

Thanking you

R. K. Sungkur

SECTION A: Demographic Information

1. What is your current role in the field of Cybersecurity?

Job Specification	*Tick one of the following*	
Information Security Officer		**1**
Information Security Analyst		**2**
Information Security Consultant		**3**
Chief Information Security Officer		**4**
Others (Please specify)		**5**

2. What is your current qualifications?

Qualifications	*Tick one of the following*	
Certificate		**1**
Diploma		**2**
Degree		**3**
Postgraduate		**4**
Other (Please specify)		**5**

3. What professional courses in the field of Cybersecurity have you followed?

Certifications	*Tick any number of applicable options*	
Certified Information Systems Security Professional (CISSP)		**1**
Certified Ethical Hacker (CEH)		**2**
Licensed Penetration Tester (LPT)		**3**
Certified Information Security Manager (CISM)		**4**
Certified Cloud Security Professional (CCSP)		**5**
EC-Council Certified Security Analyst (ECSA)		**6**
CompTIA Security+		**7**
Certified Network Defender Certification (CND)		**8**

Offensive Security Certified Professional (OSCP)		**9**
Others (Please specify)		**10**

4. Employment type *Tick one option* Permanent ☐ Contract ☐

5. Indicate your age group. *Tick one of the 5 options*

	Tick one of the following	
18-30		**1**
31-40		**2**
41-50		**3**
51-60		**4**
Above 60		**5**

6. Gender Tick one option Mal ☐ Female ☐

7. Number of years of experience in the field of Cybersecurity

	Tick one of the following	
0-5		**1**
6-10		**2**
11-15		**3**
15-20		**4**
More than 20		**5**

SECTION B: Understanding the current situation.

Tick *one* option

	1	2	3	4	5
Statement	**Strongly Disagree**	**Disagree**	**Not Sure**	**Agree**	**Strongly Agree**
1. Cybersecurity is a highly dynamic field					
2. There is a growing need for Cybersecurity experts in Mauritius					
3. Up-skilling and re-skilling in the field of Cybersecurity are important.					
4. Current techniques used for continuous learning in your company are effective.					
5. You feel confident about your skills required at work.					

SECTION C: Perceived Ease of Use of the SMART Learning Environment

Tick *one* option

	1	2	3	4	5
Statement	**Strongly Disagree**	**Disagree**	**Not Sure**	**Agree**	**Strongly Agree**
1. The User Interface of the SMART Learning Environment promotes easy use.					
2. The SMART Learning Environment is easy to use.					

SECTION D: Perceived Usefulness of the SMART Learning Environment

Tick *one* option

	1	2	3	4	5
Statement	**Strongly Disagree**	**Disagree**	**Not Sure**	**Agree**	**Strongly Agree**
1. The SMART Learning Environment is effective in providing personalised learning materials.					
2. The SMART Learning Environment is correct in its operations.					

SECTION E: Attitude towards Using the SMART Learning Environment

Tick *one* option

	1	2	3	4	5
Statement	**Strongly Disagree**	**Disagree**	**Not Sure**	**Agree**	**Strongly Agree**
1. The SMART Learning Environment offers a motivating and engaging learner experience.					
2. The SMART Learning Environment provides a better learning experience as compared to existing methods of training.					

SECTION F: Intention to Use the SMART Learning Environment

	1	2	3	4	5
Statement	**Strongly Disagree**	**Disagree**	**Not Sure**	**Agree**	**Strongly Agree**
1. The SMART Learning Environment can be used for the training of Cybersecurity Professionals in Mauritius.					

2. The SMART Learning Environment can be used for the training of ICT Professionals in other areas such as Networking and Software Engineering					

SECTION G: Further Improvements

Comment on possible improvements to the proposed SMART Learning Environment

Respondent:
……
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Annexure F – Gatekeeper's Permission Letter from MTCI

REPUBLIC OF MAURITIUS

MINISTRY OF TECHNOLOGY, COMMUNICATION AND INNOVATION

My Ref: MTCI/E/104

05 March 2019

Gatekeeper permission letter for PhD

Would you please refer to your email dated 24 January 2019 regarding the above subject.

2. I am directed to inform you that this Ministry has no objection to allow you to conduct research on your project titled "*Bridging the Training Needs of Cybersecurity Professionals in Mauritius through the use of SMART Learning Environments*" on the following terms and conditions:

(a) the interview should be a one to one;

(b) all formalities which have to be done between interviewer and interviewee should be in line with PhD protocols;

(c) the interview should be carried out at a date and time convenient to the interviewee;

(d) collected data will be used for the purpose of your research only;

(e) participation of this Ministry and officers in the research is voluntary and that they are free to withdraw at any time, without giving a reason and that this will not affect legal rights; and

(f) any personal information collected during the study will be anonymised and remain confidential.

3. In case of any concern or any additional information is required, this Ministry reserves the right to contact you for any clarification.

Yours faithfully,

V. Jhugroo (Mrs)
for Permanent Secretary

Mr Roopesh Kevin SUNGKUR
Senior Lecturer
Department of Software and Information Systems
Faculty of Information, Communication and digital Technologies
University of Mauritius
REDUIT

Level 6, SICOM Tower, Wall Street, Ebene– Republic of Mauritius
Tel : (230) 401 3500 E-mail: mtci@govmu.org Website : http://mtci.govmu.org

Annexure G – Full Ethical Clearance from UKZN

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

18 March 2019

Mr Roopesh Kevin Sungkur (216076365)
School of Management, IT & Governance
Westville Campus

Dear Mr Sungkur,

Protocol reference number: HSS/0002/019D
Project title: Bridging the training needs of Cybersecurity Professionals in Mauritius through the use of SMART Learning Environments

Approval Notification – Expedited Application

With regards to your response received on 05 March 2019 to our letter of 21 February 2019, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. **PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.**

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

....

Dr Rosemary Sibanda (Chair)

/ms

cc Supervisor: Professor MS Maharaj
cc Academic Leader Research: Professor Isabel Martins
cc School Administrator: Ms Angela Pearce

Humanities & Social Sciences Research Ethics Committee
Dr Rosemary Sibanda (Chair)
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Telephone: +27 (0) 31 260 3587/8350/4557 **Facsimile:** +27 (0) 31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za / mohunp@ukzn.ac.za
Website: www.ukzn.ac.za

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Annexure H – Expert Reference Group Discussion Data

Theme: Relevance of the SMART Learning Environment to address the research problem		
Subtheme 1: Expressing the problem situation	**Subtheme 2:** Possibility of addressing the problem through current means available	**Subtheme 3:** Appropriateness / usefulness of the proposed SMART Learning Environment
"Indeed there is a serious mismatch and ability of the country to produce Cybersecurity professionals to address the needs of the ICT Industry. This is causing a serious impediment on the growth of this sector which is a one of the pillars of the Mauritian Economy. Besides this, the area of Cybersecurity is a fast-evolving one and these professionals need to be constantly updated about the latest trends, techniques and technologies." (Respondent 2)	"Recently, there has been much hype about MOOCs which were supposed to bring a revolution in tertiary education with a cascading effect, eventually, in the ICT Industry. However, in 2019, after years of operation it is still being noted that the completion rate is distressingly low. This can perhaps be accounted to the fact that the concept of sage-on-the-stage works to a certain level but after that the learners would want more individual attention and materials that are more adapted to their specific maturity and expertise level." (Respondent 1)	"The idea of providing personalised learning materials to Cybersecurity Professionals through intelligent techniques looks interesting. It may address the problems raised so far during the discussion. It is to be pointed out that the problem that we are talking about is of national level and we need to find a solution not only for the immediate term but also one that is sustainable in the future as well. Going forward with the idea of using SMART Learning Environments for continuous up-skilling of ICT professionals can prove to be more effective as compared to the existing means." (Respondent 5)
"I know one company which wanted to move one of its processes from the US to Mauritius but when time came for recruitment, the company received only 175 applications. The company wanted to recruit	"The tertiary-education providers of the country can provide the necessary training up to a certain level but after that Cybersecurity professionals need to keep up with the fast-evolving	"The Government of Mauritius envisages to position Mauritius as a pioneer in the field of AI in the region and has even created an AI Council at National Level (Mauritius Artificial Intelligence Council. Mauritius

around 900 professionals and eventually had to drop this idea of outsourcing due to lack of properly trained ICT professionals in Mauritius." (Respondent 1)	discipline or else, their knowledge will rapidly become obsolete. Online training can be seen as a solution but the problem remains the fact that the training needs of each of these Cybersecurity professionals remain different. One may get bored with learning materials that they see as too easy or elementary and another one may get discouraged and lost with training materials that they perceive as too difficult." (Respondent 4)	has been striving hard to move from a middle-income economy and is striving hard to become a developed economy. Arguments are like, just as Mauritius had created a first-mover advantage in the textile industry in the 1980's and in the global business / offshore in the 1990's in the region, now it is time for Mauritius to gain this first-mover advantage in the field of AI for the region. The topic of SMART Learning Environment is directly in line with the vision of the Government and such a research will definitely have the keen interest of the Government of Mauritius." (Respondent 1)
"The Government of Mauritius has acknowledged that unemployment amongst young graduates has taken an alarming proportion and through the Human Resource Development Council (HRDC) has even established the Graduate Training for Employment Scheme (GTES), where the HRDC provides the monthly stipend where the unemployed graduate is given the necessary training in a company so as to have some working experience and become fit for workplace.	"Regular Up-skilling and training via face-to-face sessions prove to be quite costly, especially in the corporate world. Besides, providing release from work for these professionals and being able to plan and coordinate all this, requires enormous effort. It is true that the benefits of such a training session can be positive, and that is debatable since at times, there are no clear mechanisms as to measure the progress of the learner in such a training session. For me, it is	"The SMART Learning Environment, once developed for this specific research, can easily be tweaked to provide training in other areas such as finance, tourism and textile, each of the three areas mentioned above, being pillars of the Mauritian Economy." (Respondent 6)

This may look much of a paradox where on one hand, we have so many graduates that are unemployed and on other the other hand, we have so many job opportunities in the ICT industry which cannot be filled due to lack of skills required or due to lack of ICT professionals. This is a clear case of mismatch and if not addressed as soon as possible will be disastrous for the ICT Industry." (Respondent 4)	imperative to find a more cost-effective, flexible and targeted approach for the training and up-skilling of Cybersecurity Professionals in Mauritius." (Respondent 3)	
"At times, in the Industry, we observe that we have graduates who have the necessary academic qualifications/degrees but who are not able to deliver, lacking certain technical skills and aptitude which is a must in workplace. Hence, stressing again on the necessity for professionals to follow appropriate technical certifications and to undergo continuous professional development and constant up-skilling to keep up with the fast-evolving pace of the ICT Industry." (Respondent 3)	"We must try to think for the coming five years and plan ahead. Current means of education and training have reached a kind of saturation point where we need to come up with new tools and techniques for running the new development lap as far as education and training is concerned." (Respondent 6)	"The flexibility provided by such a learning environment is interesting especially if we consider that the target consist of working professionals who have a very busy agenda." (Respondent 3)

Annexure I – Visual Representation of Survey Results

Section A: Demographic Information

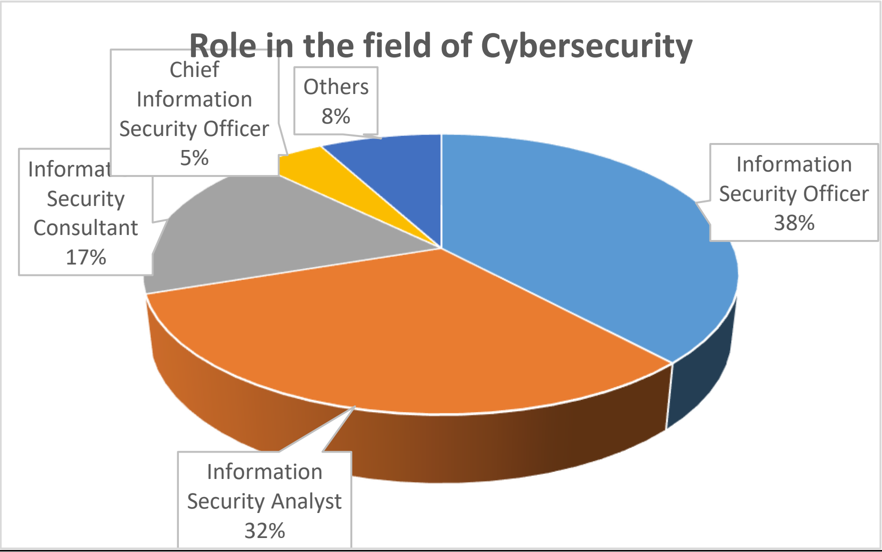

Figure A1: Current role in the field of Cybersecurity

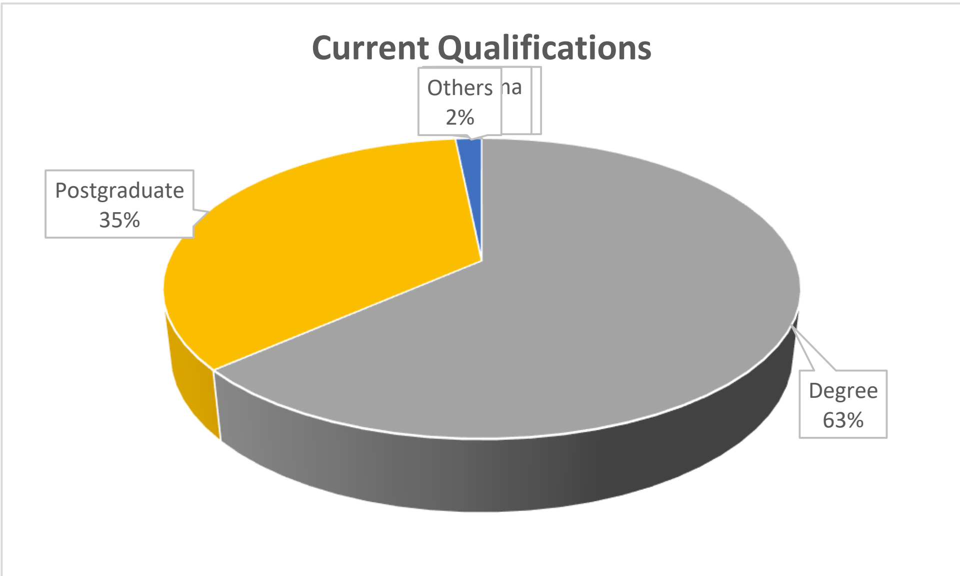

Figure A2: Current Qualifications

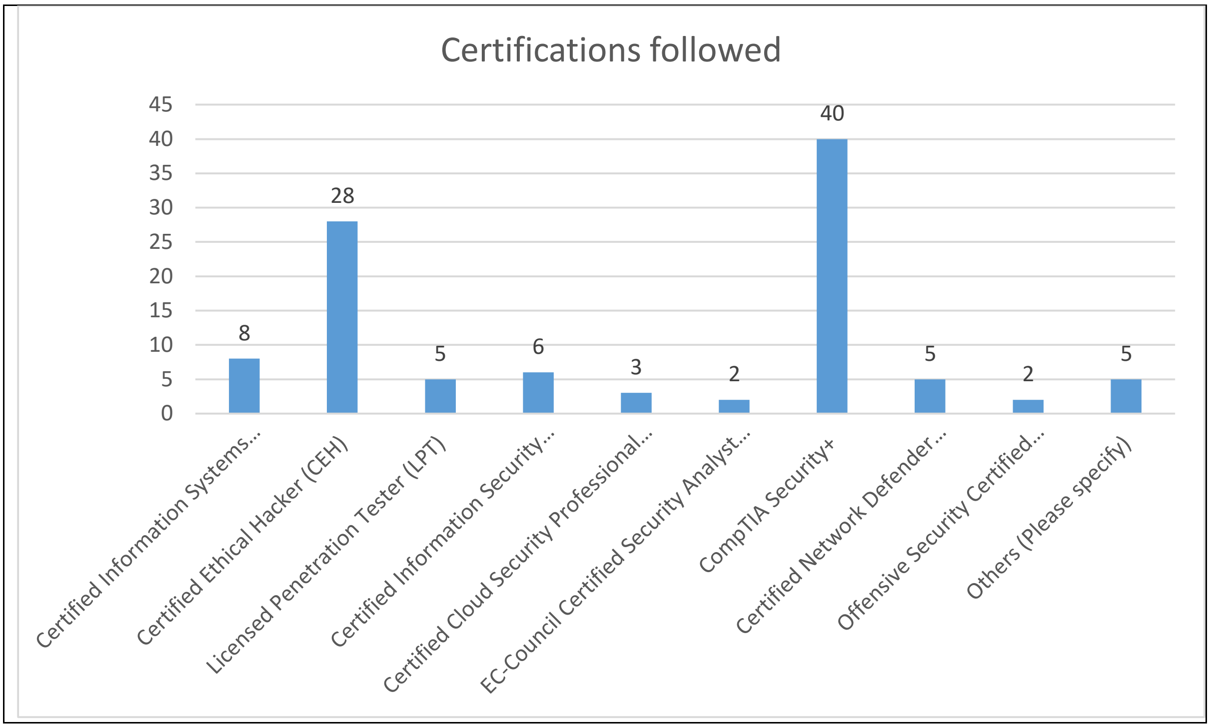

Figure A3: Certifications followed

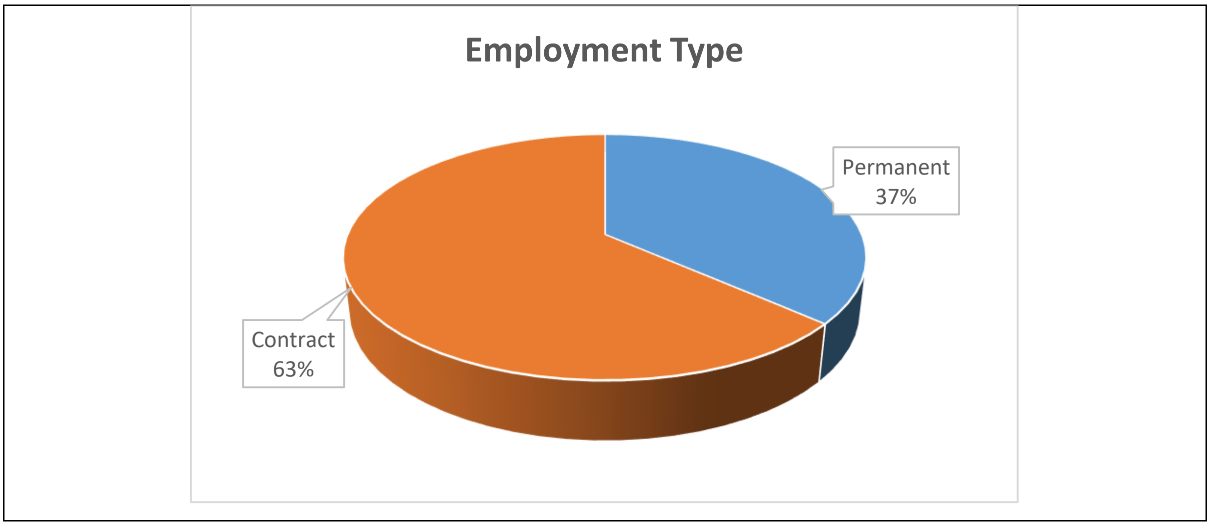

Figure A4: Employment Type

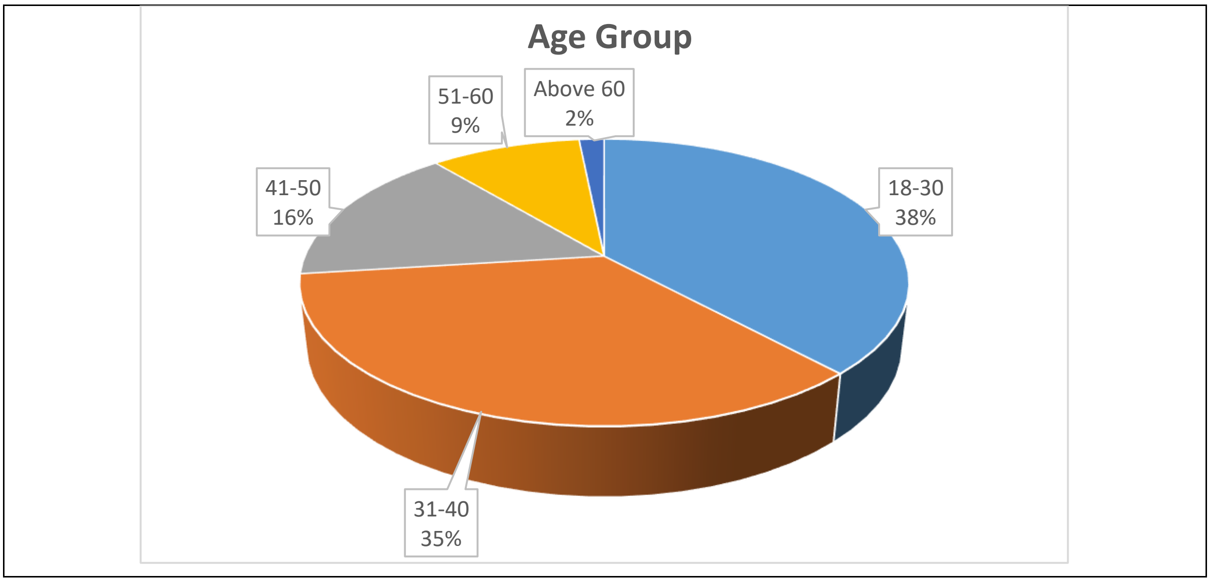

Figure A5: Age Group

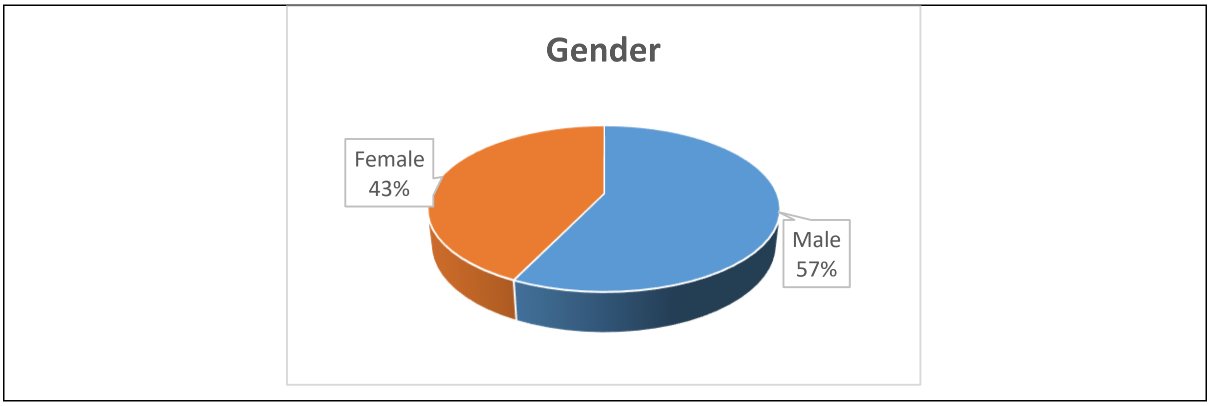

Figure A6: Gender

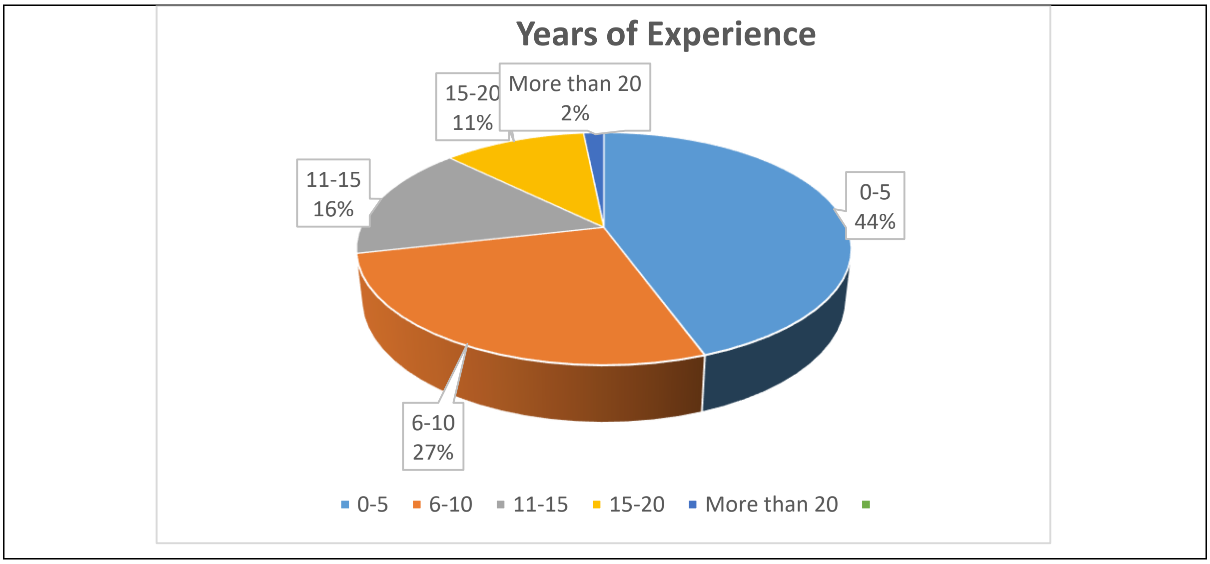

Figure A7: Years of Experience

Section B: Understanding the current situation

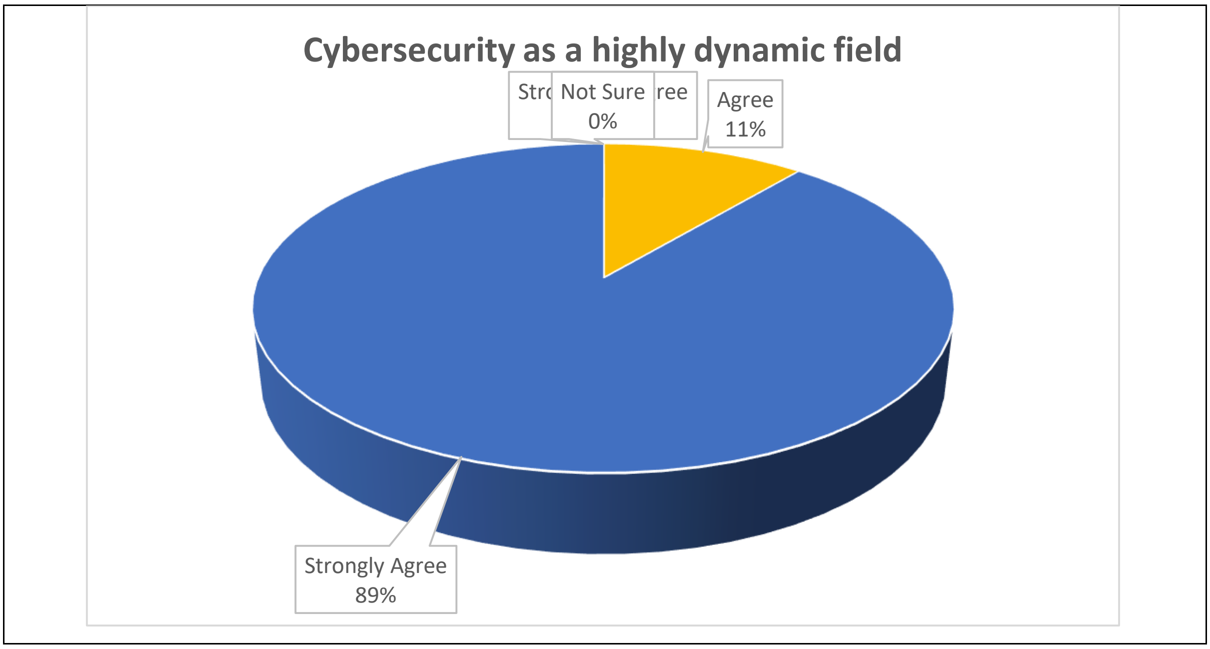

Figure A8: Cybersecurity as a highly dynamic field

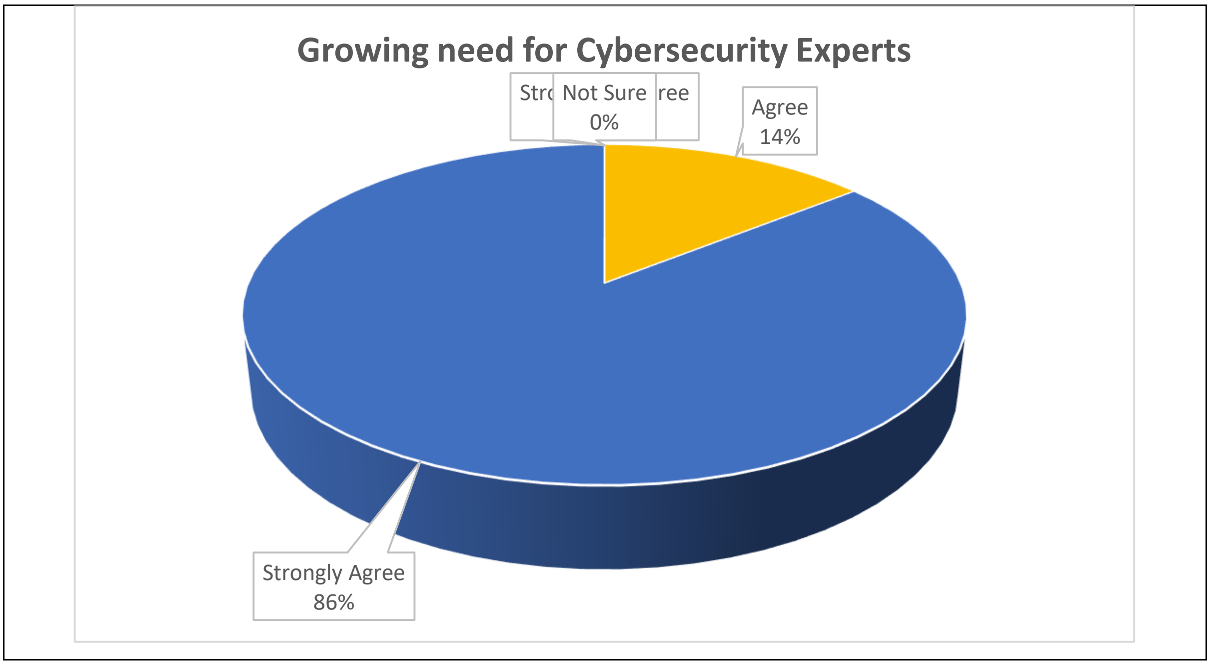

Figure A9: Growing need for Cybersecurity Experts

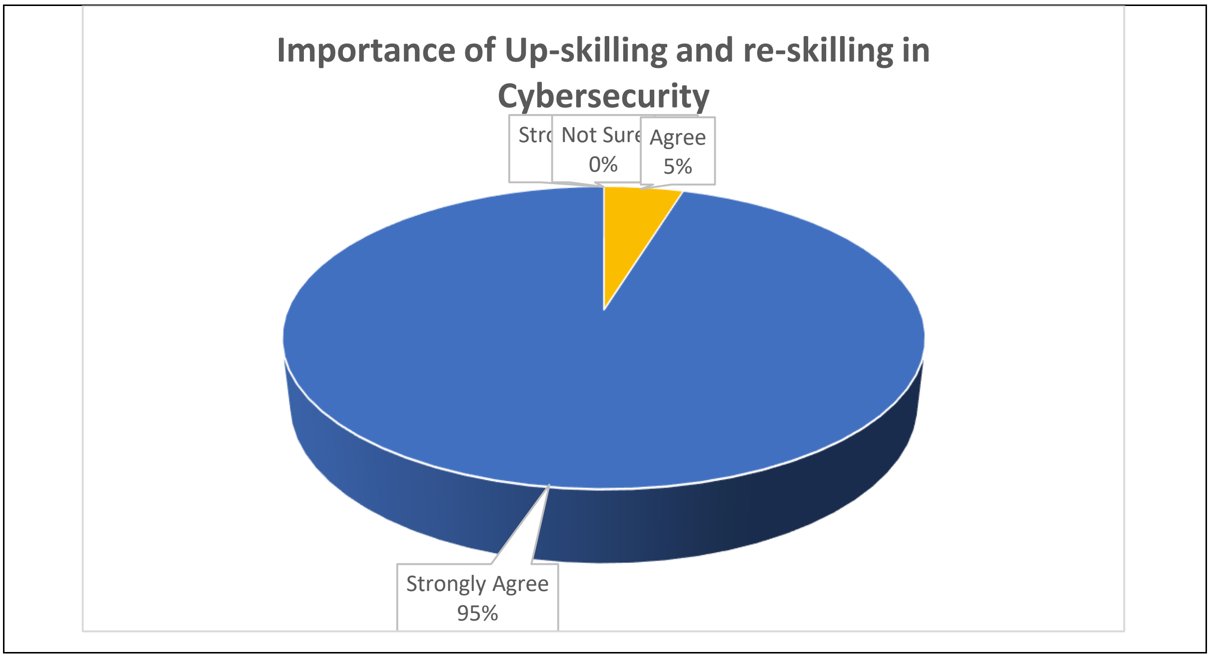

Figure A10: Importance of Up-skilling and re-skilling in the field of Cybersecurity

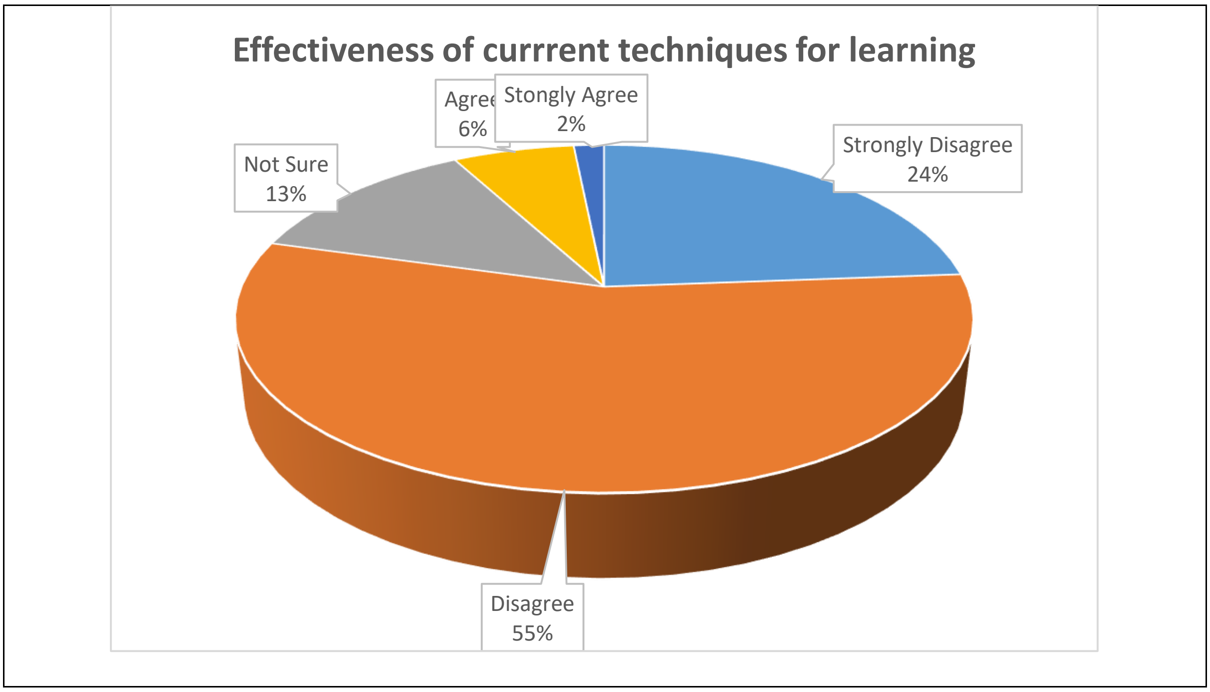

Figure A11: Effectiveness of Current Techniques for Learning in the company

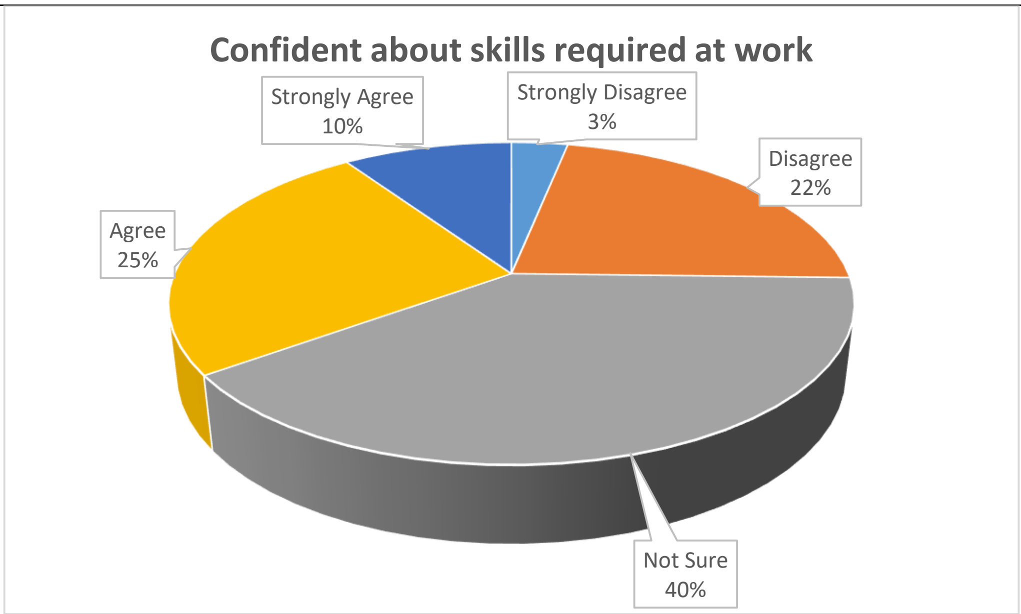

Figure A12: Confident about skills required at work

Section C: Perceived Ease of Use of the SMART Learning Environment

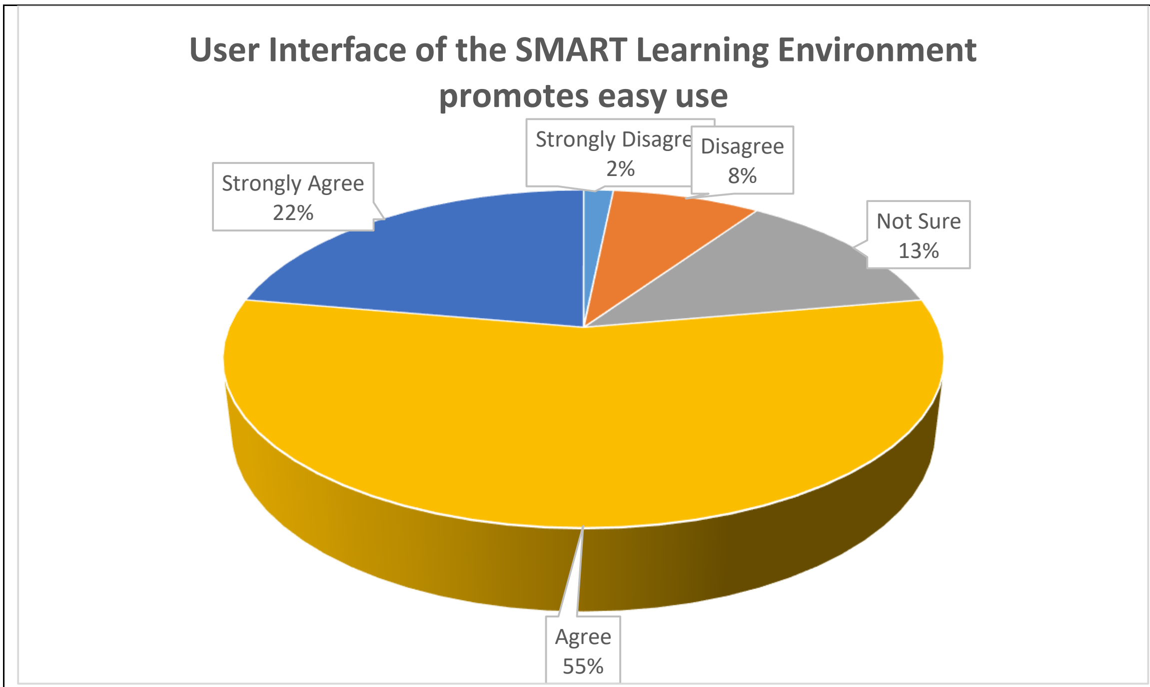

Figure A13: User Interface of the SMART Learning Environment promotes easy use

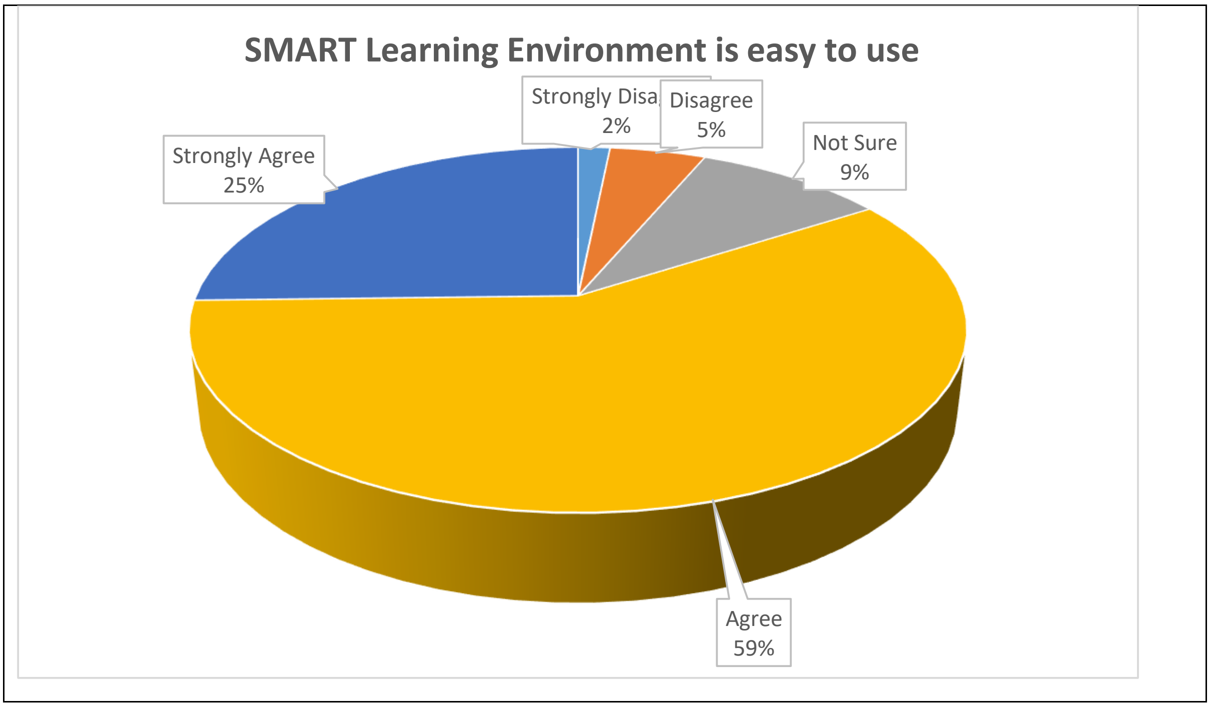

Figure A14: SMART Learning Environment promotes is easy to use

Section D: Perceived Usefulness of the SMART Learning Environment

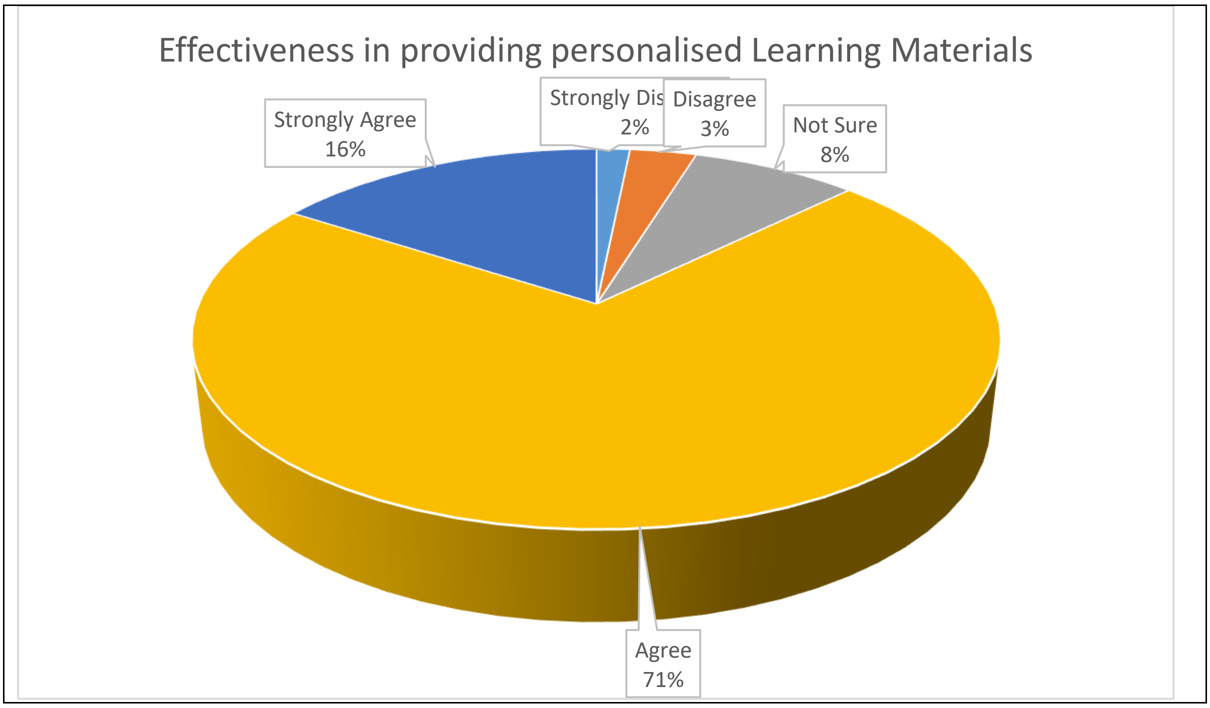

Figure A15: Effectiveness in providing personalised learning materials

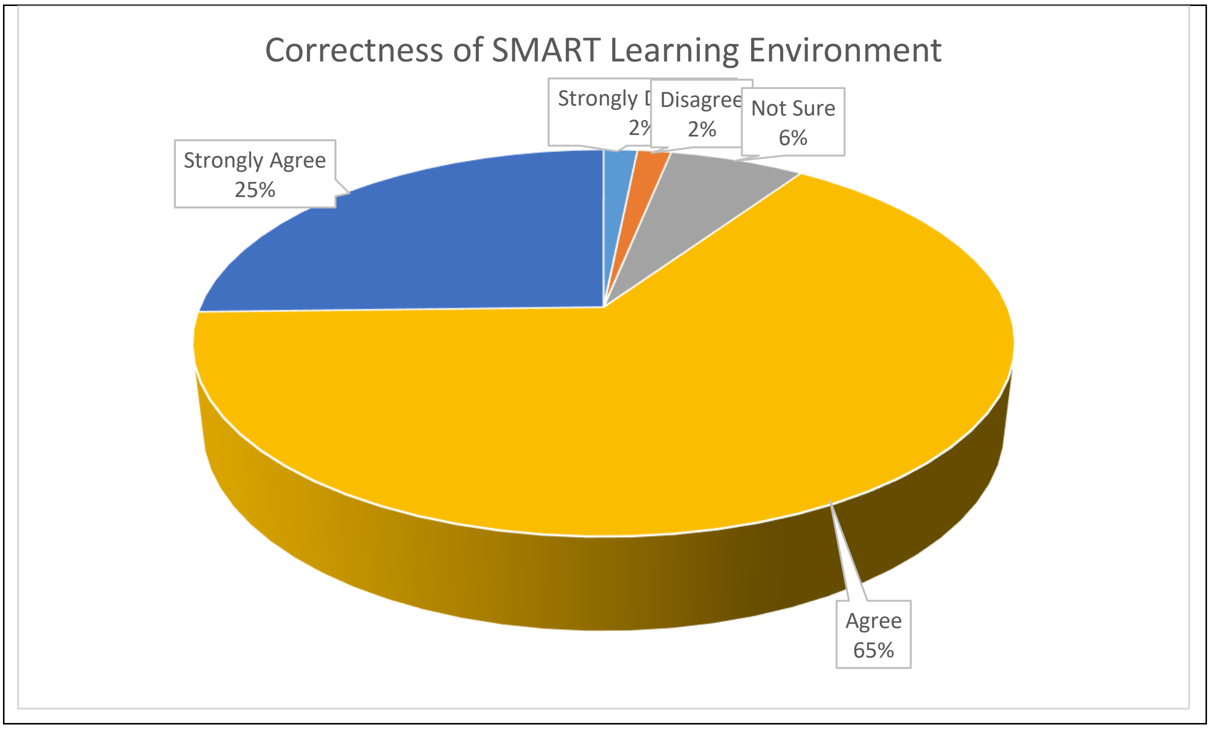

Figure A16: Correctness of the SMART Learning Environment

Section E: Attitude towards Using the SMART Learning Environment

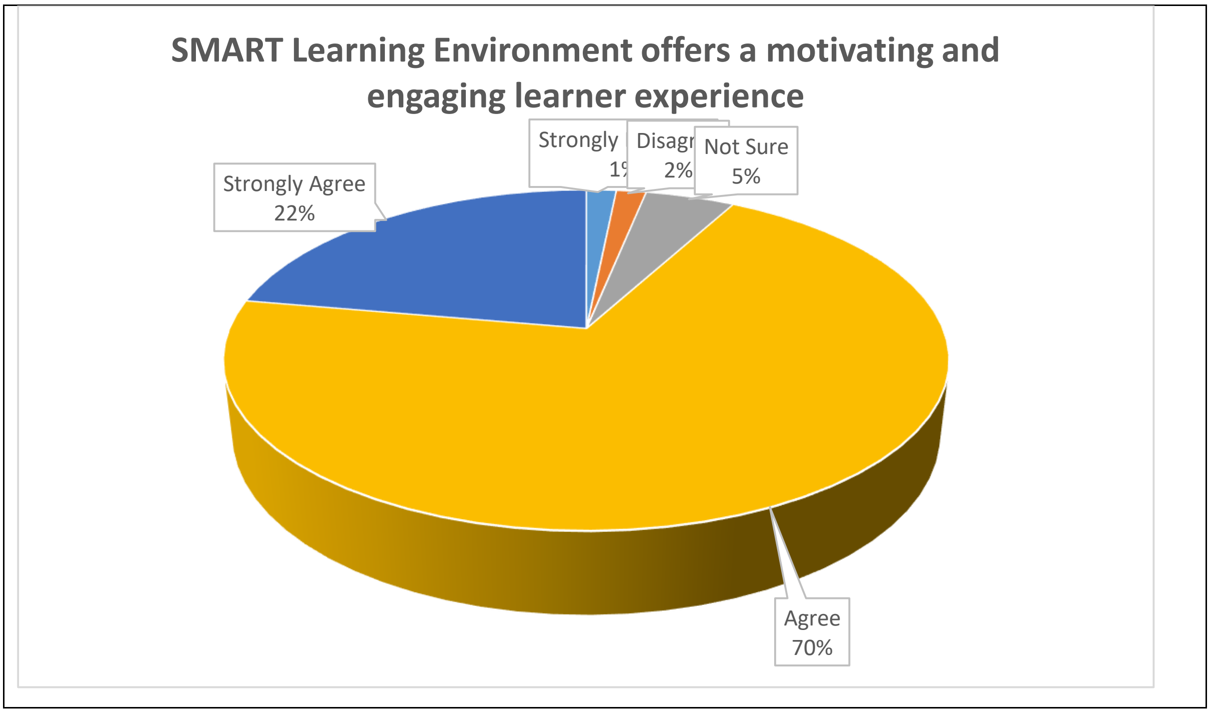

Figure A17: SMART Learning Environment offers a motivating and engaging learning experience

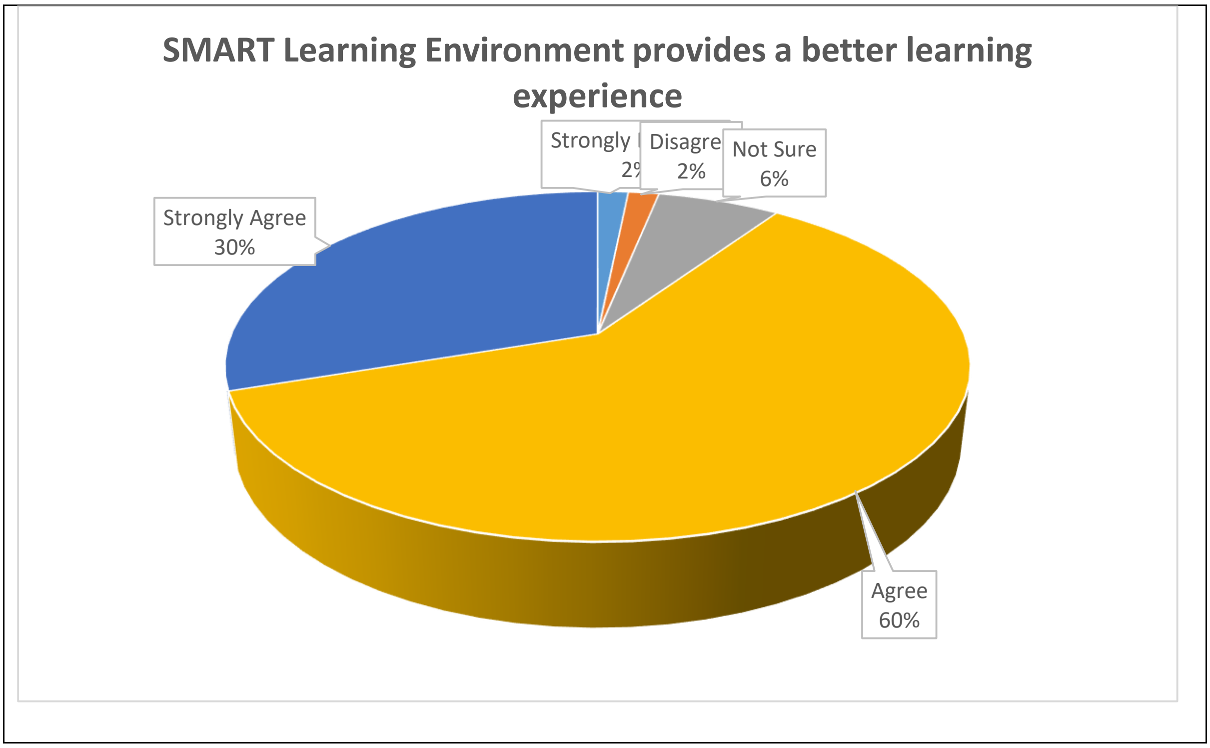

Figure A18: SMART Learning Environment provides a better learning experience

Section F: Intention to Use the SMART Learning Environment

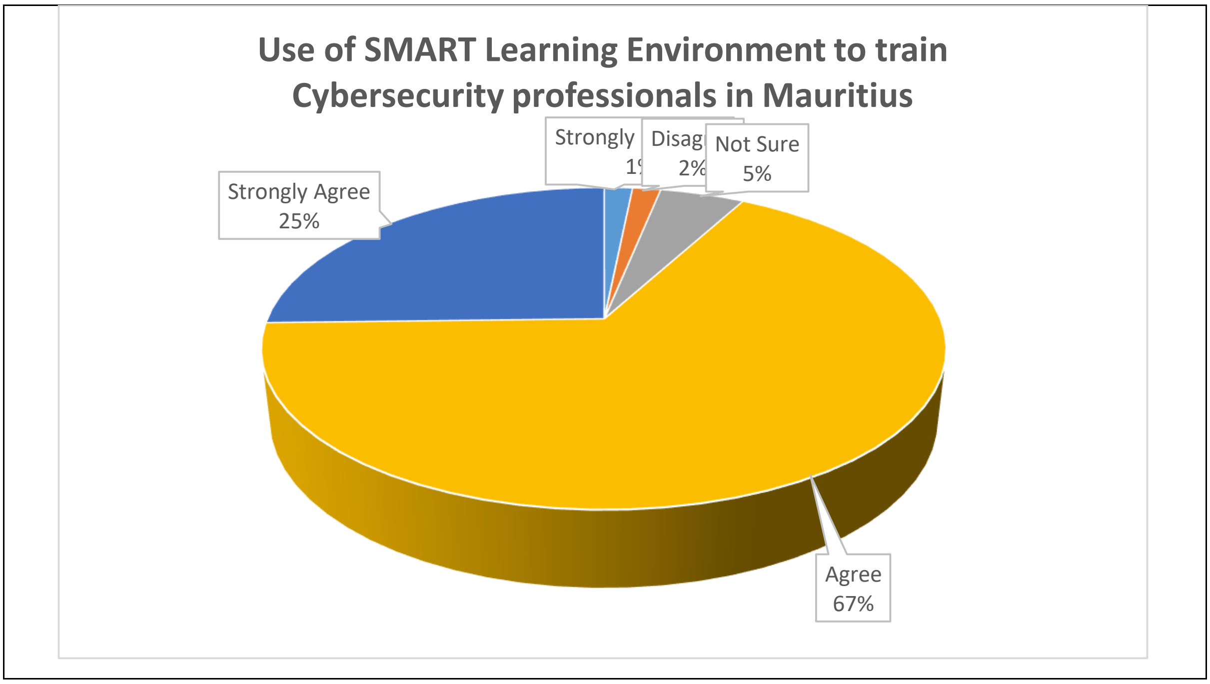

Figure A19: Use of SMART Learning Environment to train Cybersecurity professionals in Mauritius

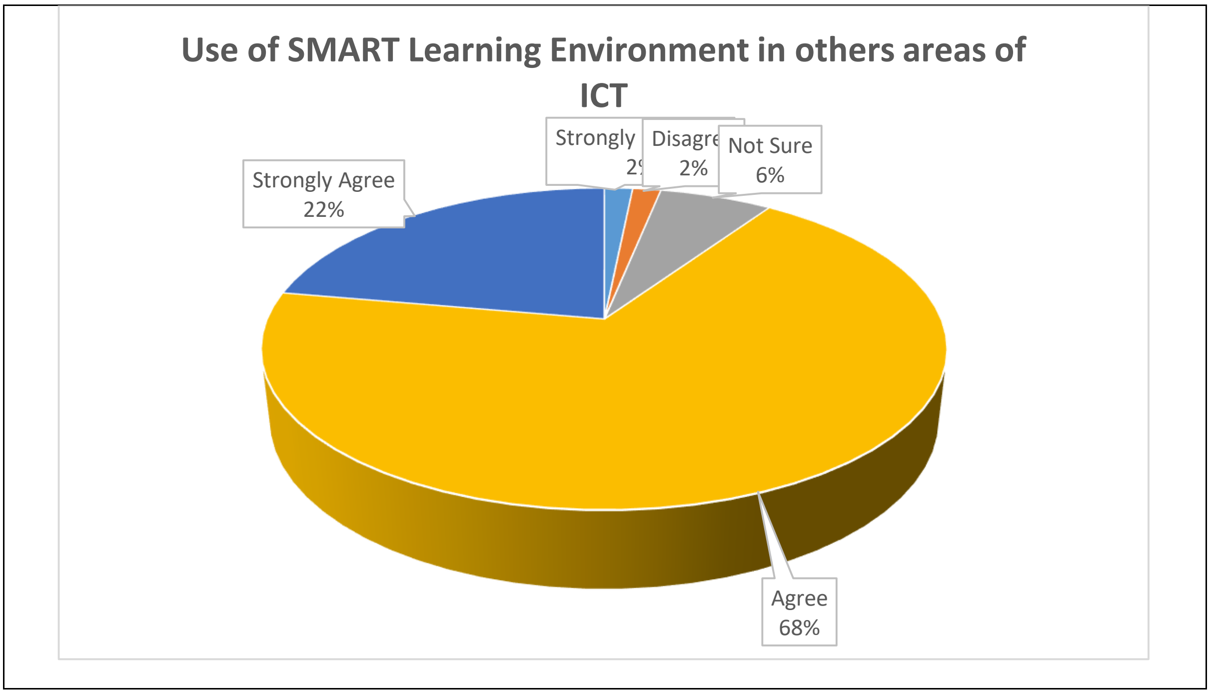

Figure A20: Use of SMART Learning Environment in others areas of ICT

Annexure J – Letter to Ministry of Technology, Communication and Innovation (TCI)

UNIVERSITY OF KWAZULU-NATAL

INYUVESI YAKWAZULU-NATALI

To: **Permanent Secretary,**

Ministry of Technology, Communication and Innovation (TCI)

Republic of Mauritius

Date: **25 January 2020**

Re: Research output from PhD

Dear Madam

First of all, please accept my deepest appreciation for your help and support for me to have been able to successfully carry out my PhD research 'Bridging the Training Needs of Cybersecurity Professionals in Mauritius through the use of SMART Learning Environments'.

The outcome of this research has been very positive and the proposed solution in the form of a SMART Learning Environment has been widely accepted by the sample of Cybersecurity professionals. A summary of the results obtained during the survey questionnaire can be found in the attached Annexure.

Hoping that this would serve as a stepping stone for future collaboration in this area.

I remain at your disposal for any further queries

Thanking you in anticipation

Yours Sincerely

Roopesh Kevin SUNGKUR

Annexure K – Turnitin Report

PhD Thesis

ORIGINALITY REPORT

9%	7%	5%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	preview-slejournal.springeropen.com Internet Source	1%
2	Tiko Iyamu, Irja Shaanika. "The use of activity theory to guide information systems research", Education and Information Technologies, 2018 Publication	<1%
3	Ya-huei Wang, Hung-Chang Liao. "Data mining for adaptive learning in a TESL-based e-learning system", Expert Systems with Applications, 2011 Publication	<1%
4	Submitted to North West University Student Paper	<1%
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