A FRAMEWORK FOR CREATING EDUCATIONAL VIRTUAL ESCAPE ROOMS TO TEACH COMPUTATIONAL THINKING

by

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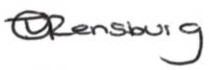

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ABSTRACT

Due to the looming Fourth Industrial Revolution, massive changes in occupations are predicted that will require a new set of skills from the next generation. As a result, educational systems are struggling to equip students with the right skills to thrive in the future. The Institute for the Future identified Computational Thinking as one of the essential skills that will be critical for success in the future workplace. Although there is no clear definition for computational thinking, many researchers have come to accept Wing's definition as an approach to solving problems, designing systems, and understanding human behavior by drawing on concepts fundamental to computer science. However, integrating computational thinking into the curriculum remains an educational challenge. Escape room games could potentially aid in the development of computational thinking skills because they immerse learners in a narrative-based, problem-solving scenario. Nicholson defines an escape room as a live-action adventure game in which players find themselves locked in a room, or series of rooms, from which they must escape within a limited amount of time.

This research study aims to illustrate a virtual escape room for teaching of computational thinking, reflect on its usefulness as a teaching tool, offer guidance on where to make improvements, and present a framework that educators can use to create their own virtual escape rooms. This research followed a Design-Based Research methodology that consisted of three iterative cycles. During the cycles, participants were given a pre-test before the virtual escape room and a post-test after the virtual escape room. Although the findings do not show a significant difference between the pre-test and post-test results, participants indicated that the experience with the escape room increased their motivation to learn more about computational thinking. This paper recommends that virtual escape rooms be investigated further since they could provide significant insight for learners in computational thinking.

Keywords: Computational thinking, game-based learning, escape rooms, virtual escape rooms

1 INTRODUCTION

"We stand on the brink of a technological revolution that will fundamentally alter how we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before" (Schwab, 2016). Schwab (2016) defines this technological revolution as the Fourth Industrial Revolution. Until now, the world has witnessed three industrial revolutions that have taken place throughout history (Ilori & Ajagunna, 2020; Schwab, 2021). The First Industrial Revolution saw the invention of steam-powered factories, the Second Industrial Revolution saw the invention of electricity that made it possible for businesses to operate and expand, and the Third Industrial Revolution was the start of digitization (Schwab, 2021; Ilori & Ajagunna, 2020). We are now at the beginning of the Fourth Industrial Revolution, where digital, biological, and physical domains are combining, and the lines between them are becoming thinner (Ilori & Ajagunna, 2020). As with the previous industrial revolutions, the Fourth Industrial Revolution will also significantly impact how humans create, exchange, and distribute value (Schwab, 2021; Ilori & Ajagunna, 2020). However, according to Schwab (2016), it is distinct for three reasons. First, its velocity: there is no historical pattern for the speed at which the current breakthroughs are happening; these breakthroughs are happening exponentially rather than in a linear way (Schwab, 2016). Second, its scope: the disruptions brought about by the Fourth Industrial Revolution affect almost every industry in every country (Schwab, 2016). Third its systems impact: the changes of the Fourth Industrial Revolution are so extensive that entire systems of production, management, and governance will be transformed (Schwab, 2016).

The Fourth Industrial Revolution will significantly impact the world of work in the next five years and beyond (Hattingh, 2018; Ilori & Ajagunna, 2020; Shahroom & Hussin, 2018). According to the World Economic Forum, today's students are expected to graduate in jobs that have not been invented yet. At the same time, a significant number of careers that exist today are prone to automation in the future (Belli, 2017). The question becomes: 'how will educational systems prepare students for a future job market beyond the boundaries of our current reality?' The Institute for the Future identified Computational Thinking as one of the essential skills that will be critical for success in the future workplace (Hattingh, 2018).

1.1 BACKGROUND INFORMATION

A significant number of individuals have started to identify computational thinking as an essential competency for students (Barr & Stephenson, 2011; Yadav, et al., 2014). With the constant evolution of technology, teachers must empower their students to become digital citizens (McClelland & Grata, 2018; Mohaghegh & McCauley, 2016). Today's students may have been born with technology in their hands, but they must be guided to know how to use it appropriately (McClelland & Grata, 2018). According to Mohaghegh & McCauley (2016), computational thinking has the potential to equip students with more than just a working knowledge of how to use computers. It enables students to become more effective problem solvers for situations beyond the computer science realm (Mohaghegh & McCauley, 2016). Over the years, a significant number of definitions for computational thinking have been attempted, but researchers still struggle to reach a consensus over what the term entails (Haseski, et al., 2018; Mohaghegh & McCauley, 2016; Cansu & Cansu, 2019; Angeli, et al., 2016). Although there is no final definition, many researchers have come to accept Wing's (2006) definition, which defines *computational thinking* as an approach to solving problems, designing systems, and understanding human behaviour by drawing on concepts fundamental to computer science.

Wing (2006) promotes computational thinking as a vital skill for the future, equating its importance to reading, writing, and basic arithmetic. She goes beyond tertiary education to state that computational thinking should be added to every child's analytical ability. As such, a growing number of educators are beginning to realize the importance of bringing computational thinking to the core of many disciplines (Mohaghegh & McCauley, 2016; Lamprou & Repenning, 2018). However, at the centre of attention are questions about how this skill can be effectively taught (Mohaghegh & McCauley, 2016; Lamprou & Repenning, 2018). According to a literature review conducted by Hsu, et al., (2018), studies have reported on the following learning methods: problem-based learning, project-based learning, collaborative learning, game-based learning, problem-solving system, scaffolding, systematic computational strategies, aesthetic experience, designed-based learning, embodied learning, HCI teaching, storytelling and universal design for learning. However, further studies have shown that the majority of these learning methods utilize computer programming. This can significantly impact students' abilities to apply computational thinking in various situations, especially when solving non-computer programming-related problems (Grover & Pea, 2013; Wing, 2008; Witherspoon, et al., 2017; Febrian, et al., 2018). According to Menon, et al., (2019), computational thinking is not just about learning to code. Instead, students need to be empowered with the necessary skills to resolve problems by thinking critically and creatively.

Various research studies have indicated that game-based learning often involves problem-solving and, therefore, can foster computational thinking skills because both computational thinking and game-based learning address problem-solving skills (Tatar & Eseryel, 2019; Durak, et al., 2017; Connolly, et al., 2008). Game-based learning has received widespread attention from researchers and practitioners in recent years due to its potential to adapt to the evolving needs of the "Net Generation" (Plass, et al., 2015; Akour, et al., 2020; Ding, et al., 2017). It is defined as a learning approach that emphasizes how games can be used during teaching and learning (Zaibon & Shiratuddin, 2009; Zaibon & Shiratuddin, 2010). Various researchers have confirmed that games' elements can give students the enthusiasm and motivation to learn naturally (Erhel & Jamet, 2013; Woo, 2014). Unlike traditional learning methods, game-based learning can be adjusted to suit the learners' skill levels to provide them with an optimal learning experience (Fotaris & Mastoras, 2019). In recent years, one game-based and gamification tool has gained tremendous popularity due to its potential to promote the learning of any chosen subject for a diverse group of learners: escape room games (Menon, et al., 2019).

Nicholson (2018) defines an escape room as a live-action adventure game where players find themselves locked in a room or series of rooms, from which they must escape within a limited time by solving a series of puzzles. Escape rooms include various problem-solving narratives that require players first to understand a problem and then apply critical and creative thinking to identify and implement a solution (Menon, et al., 2019; Nicholson, 2018). Apart from immersing players in problem-solving narratives, escape rooms also offer educators the flexibility to integrate any chosen subject within the theme of the game (Menon, et al., 2019; Nicholson, 2018). According to a study conducted by Menon, et al., (2019), escape games have the potential to develop computational thinking skills. The study analyzed six games that supported the development of computational thinking skills. Of the six games, only three met the characteristics of an escape room game, as defined by Nicholson (2018), all of which were unplugged (Apostolellis & Stewart, 2014; Berland & Lee, 2011; Wang, et al., 2011; Kazimoglu, et al., 2012).

1.2 PROBLEM STATEMENT

Various initiatives have been created to support the development of computational thinking through educational escape rooms; however, most initiatives are aimed at unplugged activities (Apostolellis & Stewart, 2014; Berland & Lee, 2011; Wang, et al., 2011; Kazimoglu, et al., 2012). Very little research has been carried out to explore the impact of virtual escape rooms on the facilitation of computation thinking skills and whether using *virtual* escape rooms is a suitable method to teach computational thinking.

The benefits that virtual escape rooms have to offer are manifold. Various studies have indicated that virtual escape rooms provide conditions for deep learning, collaborative problem-solving, and active engagement, allowing students to demonstrate knowledge, apply skills, adopt acceptable behaviors, inspire critical thinking, and guide decision-making. Furthermore, they have shown potential for enhancing soft skills, promoting teamwork, the ability to work under pressure, communication skills, and student motivation (Sánchez-Ruiz, et al., 2022; Cai, 2022; Torres, et al., 2022; Ang, et al., 2022; Anton-Solanas, et al., 2022). According to Lathwesen & Belova (2021), there are still a few obstacles regarding virtual escape rooms that need to be addressed, including the need for practical design frameworks to assist educators in creating these learning environments.

Due to the limited number of research studies on this topic, the researcher feels there is an opportunity to expand the current research by developing a framework for the creation of virtual escape rooms that can be used in higher education to teach computational thinking.

1.1 PURPOSE OF THE STUDY

This study aims to determine how virtual escape rooms can be used as a teaching method for computational thinking. The outcome of this study includes both a practical and theoretical outcome. The practical outcome is the virtual escape room, while the theoretical outcome is the framework that guides the implementation of the virtual escape room for teaching computational thinking.

1.3 RESEARCH QUESTIONS

The research aims to answer the following research questions:

1.3.1 Research Question

What are the components of a framework guiding the use of virtual escape rooms in the teaching of computational thinking?

1.3.2 Sub-Research Questions

- What are the benefits of virtual escape rooms used in education?
- How are virtual escape rooms used in education?
- How can the use of virtual escape rooms develop computational thinking skills?

1.4 ASSUMPTIONS

The assumptions regarding this study include the following:

- The participants are committed to the escape room and will be fully involved in it.
- The participants will give honest answers to the pre-and post-test and the evaluation questionnaire.
- The participants will complete the activities in the order the researcher gave.
- The participants will apply their knowledge from the pre-test questionnaire in the virtual escape room to solve the puzzles.

1.5 DELINEATIONS

To narrow the scope of the research project, the research dissertation is only concerned with first year programming students from the department of Informatics at the University of Pretoria.

1.6 BRIEF CHAPTER OVERVIEW

1.6.1 Chapter 1: Introduction

This chapter will provide the background information (consisting of computational thinking, game-based learning, and virtual escape rooms), the problem statement, the purpose of the study, the research questions, the assumptions, the delineations, and the chapter map. The introduction chapter will allow the audience to understand the content of the problem addressed in this research study.

1.6.2 Chapter 2: Literature Review

This chapter will provide detailed information about computational thinking (components of computational thinking, computational thinking in education, computational thinking assessments, and the integration of computational thinking into the curriculum), game-based learning (escape rooms, and virtual escape rooms), how escape rooms can be used to facilitate computational thinking, and frameworks for creating educational escape rooms.

1.6.3 Chapter 3: Methodology

The chapter provides a methodology structure used to gather evidence. It contains a detailed plan of how the researcher conducted the study, including the research philosophy, research strategy, data collection methods, and data analysis methods utilized in the study. The chapter will also provide an overview of the ethical considerations that guided the research design and practices of the study.

1.6.4 Chapter 4: Analysis of Findings

This chapter will analyse the data according to the methods specified in the previous chapter and discuss the findings.

1.6.5 Chapter 5: Discussions and Conclusions

The chapter will provide a summary of the data that was analysed in chapter 4. It will also attempt to answer the research question.

1.6.6 Chapter 6: References

The reference list will include all the sources that has been used during this research paper.

1.7 CONCLUSION

The introduction section provides insight into the content of the thesis. The chapter contains the background information, problem statement, purpose statement, research questions, assumptions, delineations, and chapter map. The background information allows the audience to understand the content of the problem, which leads to the purpose of the thesis. The purpose statement explains why the problem statement should be answered.

2 LITERATURE REVIEW

2.1 INTRODUCTION

Industrial revolutions have fundamentally changed our society and economy throughout history, each building upon the innovations and technologies of the previous revolution, thus leading to more advanced forms of production. We are currently experiencing the latest revolution, the fourth industrial revolution (Nayyar & Kumar, 2020; Park, et al., 2017; Xu, et al., 2018; Bloem, et al., 2014; Kayembe & Nel, 2019).

The fourth industrial revolution, a term coined by Klaus Schwab, describes a world characterized by the fusion of technologies blurring the lines between the physical, digital, and biological spheres (Ilori & Ajagunna, 2020; Schwab, 2016). According to Schwab (2016), the fourth industrial revolution is one of the most profound industries ever witnessed because it disrupts almost every industry in every country. The breadth and depth of these changes are so extensive that entire production, management, and governance systems are transformed. As a result of the rapid pace of change and increasingly powerful and disruptive technologies that have arisen from the fourth industrial revolution, the world of work is unknown and unpredictable.

Students need an educational system to prepare them for the world they will be walking into (Hattingh, 2018). However, according to Forum (2016), more than 35% of the critical skills for today's workers will have changed significantly in the next five years. For students starting a 4-year technical degree, half of the knowledge they obtain in their first year of study will be outdated by the time they finish their degree. The question becomes: Are the current education and training enough to prepare students for an unpredictable future? As the oft-quoted saying from Richard Riley goes: "***We are currently preparing students for jobs that don't yet exist … using technologies that haven't been invented … in order to solve problems we don't even know are problems yet***." How will educational systems empower the current workforce with the right skills if more than 35% of the skills we consider important today will have changed in the next five years and beyond? According to Davies, et al., (2011), computational thinking is the key to future success.

2.2 COMPUTATIONAL THINKING

Computational thinking may seem like a new concept, but it dates back to the 1900s. The phrase "Computational Thinking" was first referenced by educationalist and mathematician Seymour Papert. He claimed that computational thinking could be the key to defining the relationship between a problem and its solutions and the structuring of data (Cansu & Cansu, 2019; Curzon & McOwan, 2017; Lodi & Martini, 2021). The term was formally coined and brought to the forefront of the computer science community due to a 2006 ACM article published by Jeannette M. Wing (Tom, 2012; Selby & Woollard, 2013; Wing, 2006). Since Jeanette Wing's use of the term computational thinking in her 2006 article, various discussions have arisen to seek a robust definition of the term (Selby & Woollard, 2013).

Throughout the years' various definitions of computational thinking have been attempted; however, researchers have not yet reached a consensus on what the term entails (Angeli, et al., 2016; Lamprou & Repenning, 2018; Mohaghegh & McCauley, 2016; Cansu & Cansu, 2019). Efforts aiming at developing a definition for computational thinking include, amongst others, the National Academy of Sciences workshop (Council, 2010), the initiative undertaken by Furber (2012), workshops organized by the Computer Science Teachers Association (CSTA) and the International Society for Technology in Education (ISTE). The definition provided by the 2010 National Research Council attempted to differentiate computational thinking from computer literacy, computer programming, and computer applications. The report broadened the term to include core concepts from the discipline of computer science, such as abstraction, decomposition, pattern generalization, visualization, problem-solving, and algorithmic thinking (Council, 2010). Furber (2012) offered a similar definition of computational thinking as "the process of recognizing aspects of computation in the world that surrounds us, and applying tools and techniques from computer science to understand and reason about both natural and artificial systems and processes." The Computer Science Teachers Association and the International Society for Technology developed, in collaboration with leaders from higher education, industry, and k-12 education, an operational definition of computational thinking as a problem-solving process that includes, but is not limited to, the following elements: (a) Formulating problems in such a way that enables us to use technology and other tools to help us solve them; (b) Organizing and logically analyzing data; (c) Represent data through abstractions, such as models and simulations; (d) Automating solutions by using algorithmic thinking; (e) Identifying, analyzing and implementing possible solutions to implement the most efficient and effective solution; and (f) Generalizing and transferring this problem-solving process to a wide variety of problems (Angeli, et al., 2016). Although there is not one unanimous definition of computational thinking, based on the literature mentioned above, researchers have come to accept that computational thinking is a thought process that utilizes components fundamental to computer science.

2.2.1 Components of Computational Thinking

The fundamental components of computational thinking are another source of divergence amongst researchers. The following table illustrates the different components used by various researchers:

Components	Source
Abstraction, Analysis and Automation	Lamprou & Repenning (2018)
Abstraction, Decomposition, Algorithmic Thinking, Evaluation and Generalization	Selby & Woollard (2013)
Abstraction, Algorithms, Automation, Problem Decomposition, Parallelization, Simulation	Barr & Stephenson (2011)
Abstraction, Automation, Analysis	Lee, et al., (2011)
Abstraction, Algorithms, Decomposition, Debugging, Generalization	Angeli, et al., (2016)
Abstraction, Algorithms, Automation, Problem Decomposition, Generalization	Wing (2006); Wing (2008); Wing (2011)
Abstraction, Decomposition, Pattern Recognition, Evaluation	Humpreys (2015)

Abstraction, Algorithmic Thinking, Problem Solving, Pattern Recognition, Design-based Thinking	Kalelioglu, et al., (2016)
Abstraction, Algorithmic Design, Decomposition, Pattern Recognition, Generalization, Inference	Mohaghegh & McCauley (2016)
Decomposition, Algorithmic Design, Abstraction, Automation	Yadav, et al., (2016)
Decomposition, Pattern Recognition, Abstraction, Algorithmic Design	Harimurti, et al., (2018)
Decomposition, Pattern Recognition, Generalization, Abstraction and Algorithmic Design	Corradini, et al., (2017)

Table 1: Components of Computational Thinking

While the exact components differ from researcher to researcher, it is clear that the essential components are largely uniform across the field. These essential components include decomposition, abstraction, generalization and algorithmic thinking:

- Decomposition is a method for taking apart problems and breaking them into smaller and more manageable sub-problems (Lamprou & Repenning, 2018; Selby & Woollard, 2013; Barr & Stephenson, 2011; Angeli, et al., 2016; Wing, 2008; Wing, 2006; Wing, 2011; Humpreys, 2015).
- Abstraction is the process of making a problem more understandable by reducing the unnecessary detail and number of variables; leading to more straightforward solutions. It makes problems easier to think about (Lamprou & Repenning, 2018; Selby & Woollard, 2013; Barr & Stephenson, 2011; Angeli, et al., 2016; Wing, 2008; Wing, 2006; Wing, 2011; Humpreys, 2015).
- Generalization is the process of formulating a solution in a generic way so that it can be applied to different problems even though the variables are different (Lamprou & Repenning, 2018; Selby & Woollard, 2013; Barr &

Stephenson, 2011; Angeli, et al., 2016; Wing, 2008; Wing, 2006; Wing, 2011; Humpreys, 2015).

- Algorithmic Thinking is the process of constructing a series of ordered steps that may be followed to provide solutions to problems (Lamprou & Repenning, 2018; Selby & Woollard, 2013; Barr & Stephenson, 2011; Angeli, et al., 2016; Wing, 2008; Wing, 2006; Wing, 2011; Humpreys, 2015).

Wing (2006) emphasizes that although computational thinking draws on various components fundamental to computer science, it is essential to realize that computational thinking is not limited to computer science and other technological fields but a skill that is of significant benefit to multiple disciplines. To reading, writing, and basic arithmetic, computational thinking should be added to every child's analytical ability. As such, the importance of teaching computational thinking as a skill has been recognized by many individuals.

2.2.2 Integrating computational thinking into the curriculum

As a result of a lacking consensus on a formal definition of computational thinking and its components, the way in which computational thinking should be integrated and assessed still remains an educational challenge (Román-González, et al., 2017; Hsu, et al., 2018; Kirwan, et al., 2022).

In a literature review conducted by Hsu, et al., (2018), researchers have reported on the following learning strategies: problem-based learning, project-based learning, collaborative learning, game-based learning, problem solving system, scaffolding, systematic computational strategies, aesthetic experience, designed-based learning, embodied learning, HCI teaching, storytelling and universal design for learning.

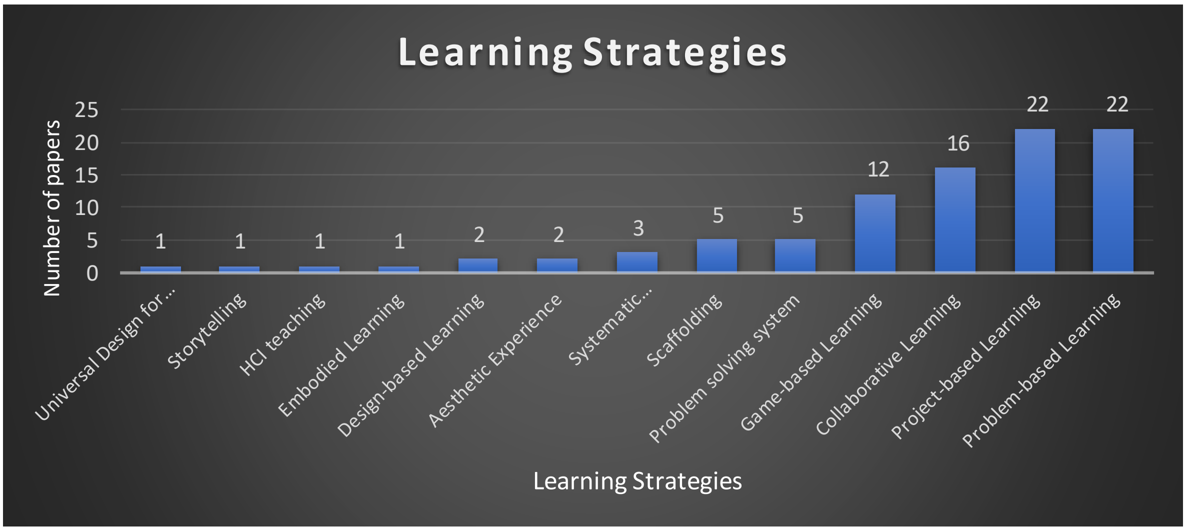


Figure 1: Computational Thinking Learning Strategies (Hsu, et al., 2018).

The study found that within the K-12 range, there was a strong research focus on problem-based, project-based, collaborative, and game-based learning. Each of these strategies will be explained in more detail below:

Problem-based learning : Problem-based learning is widely used in computational thinking activities because it brings various authentic problems into the class. It consists of the following: read the problem statement, address the questions and variables, design a solution, construct the model, test the model, make some recommendations and reflect on the problem-solving process. Problem-based learning allows students to establish new knowledge from the problems occurring in the real world as a learning context. Students will acquire analytical thinking and problem-solving skills and, at the same time, knowledge according to their subject field (Muliyati, et al., 2020; Chachiyo, et al., 2020).

Project-based learning : Project-based learning focuses on learning by doing by using ideas fundamental to science, where students can create computational models by defining a phenomenon and then testing, debugging, and refining their understandings of the relationships and processes of phenomena they notice in the world. In project-based learning, activities are driven by an overall question, with students showcasing their products often through a final competition (Yang, et al., 2020; Shin, et al., 2021).

Collaborative learning : During collaborative learning, particular forms of interaction are expected to occur, which would trigger learning. Individuals negotiate and share meanings relevant to the problem-solving task at hand. Collaborative interactions between students in different disciplines can promote a disciplinary notion of computational thinking and an interdisciplinary notion of computational thinking that fosters the transfer of computational thinking concepts across all disciplines (Chowdhury, et al., 2018).

Game-based learning : Game-based learning describes an environment focused on achieving particular learning objectives through gameplay (Trybus, 2015; Kirriemuir & McFarlane, 2004; Prensky, 2003). Spires (2015) quoted that game-based learning is not simply designing games for students to play with but instead designing learning activities that can convey learning concepts and help guide students toward an end goal. The learning activities in game-based learning involve problem-solving spaces and challenges that provide learners with a sense of achievement (Qian & Clark, 2016).

According to Boyle, et al., (2016) and Plass, et al., (2015), game-based learning applications are an increasingly important approach in cognitive training, learning, and educational interventions due to their ability to keep learners motivated to play and interact with the application or learning environment. Furthermore, recent research has indicated that game-based learning may be more effective when it comes to learning and retention than conventional instruction methods (Boyle, et al., 2016; Plass, et al., 2015). In a study conducted by Kirwan, et al., (2022), an instructional framework called ADAPTTER was created to teach computational thinking to second-level students. The framework consists of the following elements: Activities, Demonstrations, Application, Pre-activation, Transparency, Theory, Exemplification, and Reflection. It enables educators to design a high-quality, engaging, practical, and effective game-based learning course to teach computational thinking (Kirwan, et al., 2022).

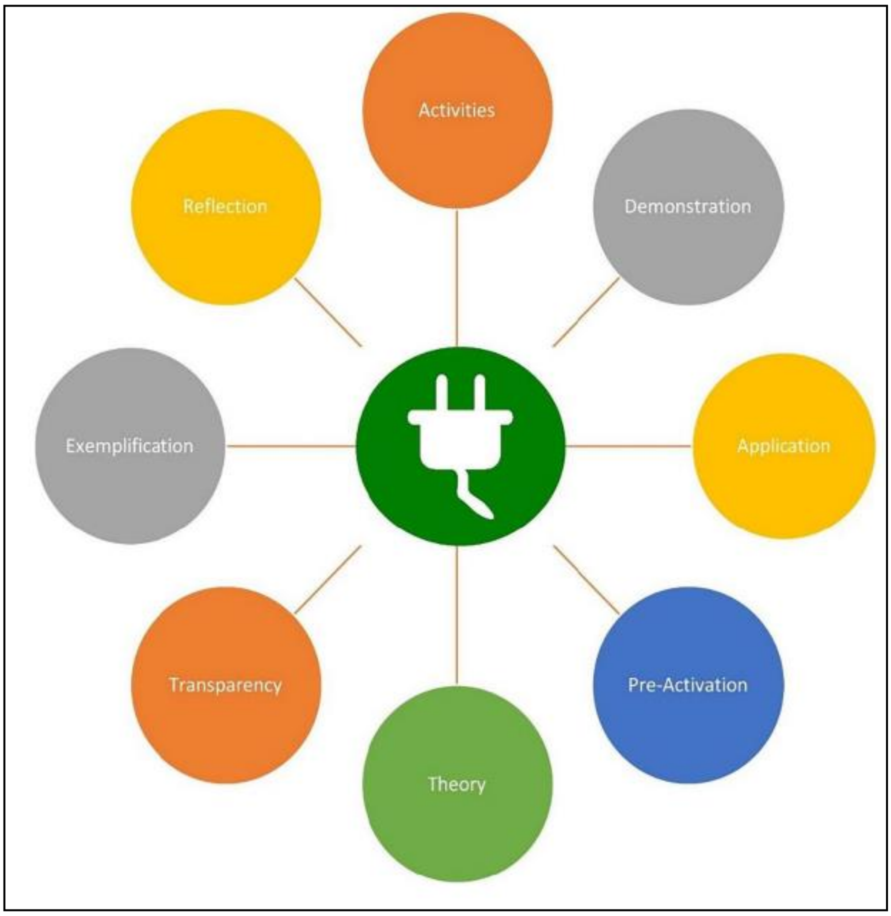


Figure 2: ADAPTTER Framework for teaching computational thinking (Kirwan, et al., 2022)

Each of these components will be explained in more detail below:

Activities: According to the study, unplugged activities are essential to teaching and learning computational thinking. The activities created for the study took the form of a puzzle or game (Kirwan, et al., 2022).

Demonstrations*:* This component was based on Merrill's (2002) First Principles of Instruction. The study found that demonstrations promoted learning and engagement, and they facilitated students approaching a problem with a base of knowledge, and clarity for the task at hand (Kirwan, et al., 2022).

Pre-Activation*:* This component was based on Merrill's "Activation" principle of instruction, where learning is promoted when learners apply existing knowledge and skills as a foundation of new skills (Kirwan, et al., 2022).

***Transparency**:* The study found that transparency is crucial in ensuring content quality and student engagement (Kirwan, et al., 2022).

***Theory**:* As mentioned previously, unplugged activities were used for teaching computational thinking; however, this approach was supplemented with theory. The study recommended that for students with no baseline of computational thinking knowledge, that explicit teaching be placed within the framework to incorporate pre-activation activities, explicit teaching, demonstration, and application of knowledge (Kirwan, et al., 2022).

***Exemplification**:* As mentioned, the design characteristic originates in Merrill's Principles for Instructions, specifically demonstrations and real-world examples. The study recommended that examples be context-specific and localised (Kirwan, et al., 2022).

***Reflection**:* This component is based on Merrill's integration principle. The study recommended that students be allowed to reflect and share their learning; however, teacher preference should be considered in its form, verbal or written (Kirwan, et al., 2022).

However, according to Román-González, et al., (2017), learning strategies are not enough to implement computational thinking into the curriculum. Without reliable and valid assessment tools, students will not be able to apply theory into practice, leading to an incomplete set of problem-solving skills. In a study by Román-González, et al., (2017), the following computational thinking assessment tools have been identified: CT diagnostic tools, CT summative tools, CT formative-iterative tools, CT data-mining tools, CT skill transfer tools, CT perceptions-attitudes scales, and CT vocabulary assessment.

***CT Diagnostic Tools**:* Computational thinking diagnostic tools aim to measure the computational thinking aptitudinal level of the subject. One of the primary advantages is that it can be administered in pure pre-test conditions (e.g., subjects without prior programming experience) and post-test conditions (i.e., after an educational intervention) to determine whether the computational thinking abilities have increased (Román-González, et al., 2017). Examples of diagnostic tools include the Computational Thinking Test (González, 2015; Román-González, et al., 2017), the Test for Measuring Basic

Programming Abilities (Mühling, et al., 2017), and the Commutative Assessment Test (Weintrop & Wilensky, 2015).

CT Summative Tools*:* Computational thinking summative tools evaluate the content knowledge of a learner after receiving some instruction in the post-test condition. Examples include a tool named Quizly (Maiorana, et al., 2015), the Fairy Assessment (Werner, et al., 2012), and the summative tools created by Zur-Bargury, et al., (2013) to measure students' understanding of computational thinking concepts after a new computing curriculum.

CT Formative Iterative Tools: Computational thinking formative-iterative tools aim to provide feedback to the learner, usually automatically, to develop and improve their computational thinking skills. These tools do not access the individual but rather their learning products, usually programming projects. They are, therefore, specifically designed for a particular programming environment. Examples include Dr. Scratch (Moreno León et al., 2015) or Ninja Code Village (Ota et al., 2016) for Scratch, Code Master for App Inventor; and the Computational Thinking Patterns CTP-Graph (Koh et al., 2010) or REACT (Koh et al., 2014) for AgentSheets.

CT Data Mining Tools: Computational thinking data mining tools are focused on the learning process. While formative-iterative tools are aimed at statistically analyzing the source code of programming projects, data mining tools, on the other hand, are more focused on retrieving and recording the learner activity in real time. These tools provide valuable insights into the data and learning analytics from which the cognitive processes of the subject can be inferred. They are instrumental in detecting gaps and misconceptions while acquiring computational concepts. Examples include the research by Grover et al., (2017) in the Blockly environment.

CT Skill Transfer Tools*:* Computational thinking skill transfer tools aim to assess to what extent the students can transfer their computational thinking skills to different kinds of problems, contexts, and situations. Examples include the Bebras Tasks (Dagiene & Futschek, 2008), the CTP-Quiz (Basawapatna et al., 2011), and the projection of computational thinking skills onto kinesthetic tasks, and visa versa (Daily et al., 2014).

These tools are especially suitable for assessing the degree of retention and transfer of computational thinking.

CT Perceptions Attitudes Scales: Computational thinking perception-attitude scales aim to assess the subjects' perceptions and attitudes about computational thinking and related issues such as computers, computer science, computer programming, or even digital literacy. Examples include the Computational Thinking Scales (CTS) (Korkmaz et al., 2017), the Computational Thinking Skills Scale (CTSS) (Durak & Saritepeci, 2018), or the Computer Programming Self-Efficacy Scale (CPSES) (Kukul et al., 2017).

CT Vocabulary Assessment*:* Computational thinking vocabulary assessment tools measure several elements and dimensions of computational thinking when the subjects verbally express them. These verbal expressions have been dominated as "computational thinking language" (Grover, 2011).

The assessment tools mentioned above all have their intrinsic characteristics, which lead them to approach computational thinking in a particular way. The diagnostic and summative tools are based on student responses to a set of pre-defined questions, while the formative-iterative and data mining tools rely on student programming creations and student activity when developing computational thinking. Each tool has a different nature, and they must all be harmonized and triangulated to reach a complete computational thinking assessment. If only one of the assessments discussed above is utilized, it can produce an incomplete view of students' computational thinking skills. This incomplete and biased view can thus lead to misunderstanding the students' computational thinking development, thus leading to the wrong educational decisions.

2.3 GAME-BASED LEARNING

The motivation behind using game-based learning is that students can interact with educational content in a playful and dynamic way, and game-based learning supports various aspects of the learning process. First, students can combine knowledge from different areas to choose a solution or make a decision (Pivec & Dziabenko, 2004). Second, learners can test how the game's outcome may change based on their decisions and actions (Pivec & Dziabenko, 2004). Third, students can interact with other team members to discuss and negotiate subsequent steps, thus improving their social and teamwork skills (Pivec & Dziabenko, 2004). According to Bouras, et al., (2004), the important aspects of games include searching for information, selecting appropriate and necessary information, developing discussion strategies for resolving conflicts, and exercising the decision-making process and negotiation. In light of these steps, the overall objective of games is to reach a consensus on a problem solution. There are currently two types of game-based learning categories that exist: digital game-based learning and non-digital game-based learning.

Perrotta (2013) describes digital game-based learning as a learning approach that utilizes digital games to support educational purposes such as teaching and learning. Erhel & Jamet (2013) describe digital game-based learning as a competitive activity in which educational goals are set to promote students' knowledge acquisition. Although designed to develop cognitive and soft skills, these games may also take on the form of simulations in which students can practice their skills in a virtual and safe environment (Anastasiadis, et al., 2018). Digital game-based learning has been introduced in various learning environments, including K-12 and higher education, due to the success and spread of the gaming industry (Squire & Jenkins, 2003). They have become a very accessible, easy-to-use, and fun learning mechanism. According to Kapp (2012), digital game-based facilitate better attitudes toward learning, increase student motivation, foster a higher order of thinking, influence personal real-life perceptions, impact decision-making processes, and aid students' learning achievement. Educators have been utilizing these benefits to facilitate learning concepts and skills that were either too time-consuming or rather disengaging for students (Ebner & Holzinger, 2007; Huizenga, et al., 2009). As with any learning approach, digital game-based learning also has its weaknesses. Digital games can be a very practical approach to simulate real-life applications when actual involvement in real-life activities is not possible or feasible; however, it does not necessarily replace physical involvement (Gillern & Alaswad, 2016). Educators also have to spend a lot of time familiarizing students with programs and technologies needed for a specific digital game, and digital games have very little space for customization (Becker, 2007; Gillern & Alaswad, 2016).

Non-digital game-based learning involves physical, board, and card game-based learning (Naik, 2014). Though less fashionable than digital game-based learning, non-digital game-based learning also provides numerous advantages. It is highly customizable, which enables educators to align games with relevant content and learning goals (Gillern & Alaswad, 2016). Non-digital games are also more accessible to students because various schools lack the technology for digital game-based learning (Gillern & Alaswad, 2016). As with digital game-based learning, non-digital game-based learning also has a few weaknesses. Educators must put much more time, effort, and planning into creating non-digital games (Gillern & Alaswad, 2016). Many of these games require resources such as print-outs, game boards, and game cards which can be challenging to maintain (Gillern & Alaswad, 2016).

Over the years, various educators have applied game-based learning in the form of educational escape rooms to increase student motivation and engagement, introduce experiential learning, and divide large tasks into more simple phases (Järveläinen & Paavilainen-Mäntymäki, 2019; Veldkamp, et al., 2020; Ross & de Souza-Daw, 2021; Menon, et al., 2019). Recent examples of educational escape room activities have been described for computer science, engineering, nursing, and chemistry. Within these activities, students have reported high levels of enjoyment, teamwork, and engagement (Ross & de Souza-Daw, 2021).

2.3.1 Escape Rooms

Escape rooms refer to real-life puzzle adventure games where players are "locked" in a room and given puzzles to solve before the time is up (Breakout, 2018; Nicholson, 2015; Clarke, et al., 2017). The concept behind escape rooms can be traced back to their online roots, where players were trapped in a room and had to interact with their environment to uncover clues to "escape" the room. These video escape games were viral among early gamers (Breakout, 2018). The first example of this "escape-the-room game" subgenre was created in 1988 by John Wilson. The game's objective was for players to enter text commands to escape a restroom (Breakout, 2018). The genre of escape rooms has progressed significantly following those early text-based and graphic-based games like MOTAS (Mystery of Time and Space), Viridian Room, and the award-winning CD-Rom game Myst. The most influential escape-the-room game by far was Toshimitsu Takagi's Crimson Room, released in 2004 (Breakout, 2018). The game was considered a runaway success with hundreds of millions of plays and has inspired the current escape room craze. The Crimson Room is a brain teaser game where players wake up in a red room with no memory. The objective of the game is to unlock the door of the room; however, to do so, players have to search the room to find certain objects that can help them with this quest (Breakout, 2018). In 2007, the Japanese company SCRAP transformed the "escape-the-room" video game concept into a live escape room. Players were locked in themed rooms where they had to solve puzzles in an allocated time to escape (Breakout, 2018). Takao Kato stated that the idea behind the transformation was to get players more involved in the game. There are about 2800 escape rooms that exist today, and the number continues to grow (Breakout, 2018).

Today escape room games can be played in a classroom, online, through board games, or even from a box. They involve a problem-solving narrative in which players are unaware of the expected outcomes (Menon, et al., 2019). They must understand a problem and identify and implement a solution to play. Escape rooms create creative learning environments that combine formal and informal learning (Lathwesen & Belova, 2021; Menon, et al., 2019). One of the most significant advantages of escape games is that educators can integrate any chosen subject within the theme of the game, which makes them suitable to accomplish any learning objectives, including those that might require certain complexity, such as computational thinking (Lathwesen & Belova, 2021; Menon, et al., 2019).

Although escape rooms are still receiving a wide degree of attention, educators are still experiencing some challenges when designing escape rooms which include: the requirement of broad space and specific equipment, the consumption of the amount of time required to prepare and conduct escape rooms, and the difficulty of embedding learning objectives into puzzles. Considering these challenges, various educators have started to navigate toward virtual escape rooms (Kuo, et al., 2022).

2.3.2 Virtual Escape Rooms

Virtual escape rooms refer to games where players attempt to "escape" a virtual environment by solving a mystery or series of puzzles (Coffman-Wolph, et al., 2017). Virtual escape rooms provide an innovative way of bringing technology and critical thinking to the classroom; their benefits are manifold (Makri, et al., 2021). They improve student motivation and the development of specific transversal competencies. Compared to physical escape rooms, they offer cost-effectiveness, accessibility, and ease of use. Furthermore, they provide conditions for deep learning and promote collaborative problem-solving skills and active engagement, allowing students to demonstrate knowledge, apply skills, adopt acceptable behaviors, inspire critical thinking, and guide decision-making (Sánchez-Ruiz, et al., 2022; Cai, 2022; Torres, et al., 2022; Ang, et al., 2022; Anton-Solanas, et al., 2022). Various studies have been conducted to illustrate the benefits that virtual escape rooms have to offer. Each of these studies will be explored in more detail below:

In a study conducted by Sánchez-Ruiz, et al., (2022), a virtual escape room was created by employing the Genial.ly platform and RPG Maker MZ software. The objective of the virtual escape room was to analyze the feelings that flourished when applying the virtual escape room in the field of Mathematics for the Bachelor in Aerospace Engineering degree. The results illustrated that the implementation of the virtual escape room significantly enhanced the generation of an environment of positive emotions. Among the feelings, motivation and enjoyment have stood out. Furthermore, students indicated that the virtual escape room activities improved their knowledge and skills. The study concluded that virtual escape rooms provide a favorable atmosphere for fostering students' positive feelings.

Figure 3: Screen captures of different quizzes designed with RPG Maker (Sánchez-Ruiz, et al., 2022)

Cai (2022) conducted a Harry Potter-themed virtual escape room to spark students' interest in chemistry and address general misconceptions. Thirty-eight students participated in the study. A pre-and post-test questionnaire and a survey were completed in addition to participating in the virtual escape room and typical online classroom. The results illustrated that the virtual escape rooms are equally as effective as a typical online lesson; however, teaching through virtual escape rooms has shown the potential of enhancing soft skills, promoting teamwork, the ability to work under pressure, communication skills, innovation competency, and increasing student motivation.

Torres, et al., (2022) conducted a similar study to improve students' basic understanding of basic concepts in chemistry and enhance student participation during the COVID-19 pandemic. Students were required to solve a mystery that covered concepts of chemical bonding, acid and base, and laboratory glassware. The results illustrated that the virtual escape room was beneficial for students mainly because it provided an innovative way of teaching chemistry, different from the traditional way.

In a study conducted by Anton-Solanas, et al., (2022), a virtual escape room was implemented to investigate nursing students' gameful experience using the GAMEX scale as part of their first-year module. In addition, the study also aimed to analyze students' motivation, learning experience and outcome of the activity, and the student's perception of the degree of achievement of the intended learning outcomes. The results illustrated that virtual escape rooms foster teamwork, communication, and critical thinking skills.

As seen from the studies presented above, virtual escape rooms can provide numerous benefits in the classroom. The following section will discuss the current escape games and how they are used to facilitate computational thinking.

2.3.3 The use of escape rooms to facilitate computational thinking

Escape rooms can potentially develop computational thinking skills because both immerse students in problem-solving scenarios. As with any competency, computational thinking can also be effectively learned when learners practice the knowledge they gain. In escape rooms, learners must apply the knowledge they gained to complete the challenges or tasks, thereby learning by doing (Resnick & Martin, 1998). Escape rooms have levels of progression which educators can use to introduce the different components of computational thinking (Menon, et al., 2019). Menon et al., (2019) systematically analysed the available games with an escape theme to develop computational thinking skills. Figure

4 illustrates a high-level overview of the games found in the research conducted by Menon, et al., (2019):

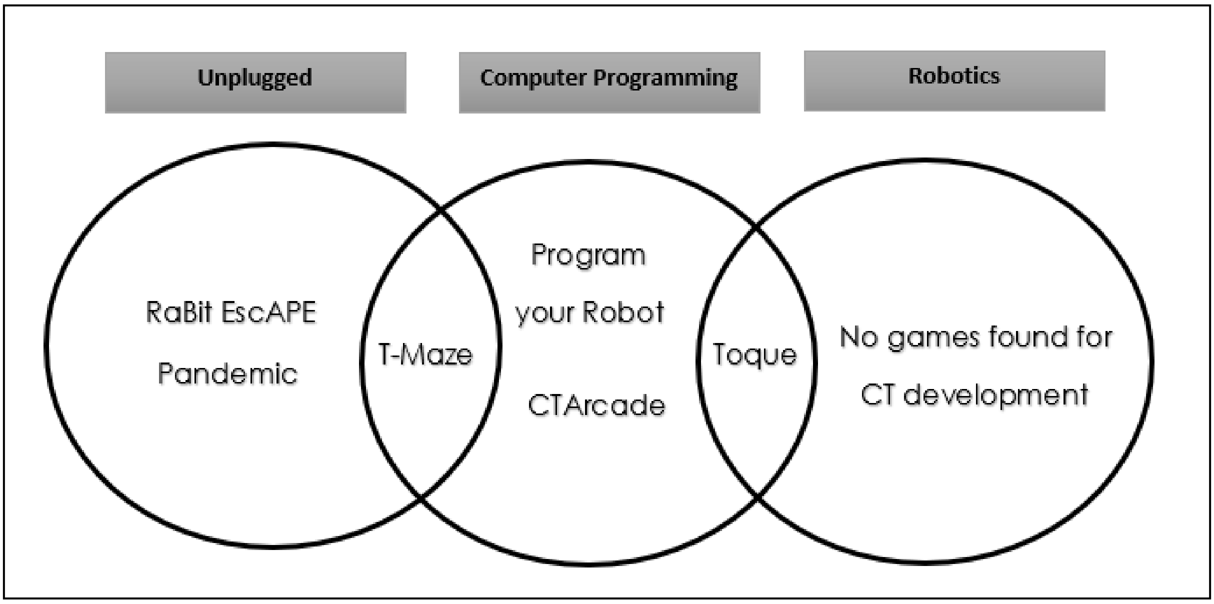


Figure 4: Games for CT Development (Menon, et al., 2019)

The study found three mediums that were used to implement games which include unplugged board games, games with computer programming and games using robotics. Each of these games are discussed below:

RabBit EscApe: Apostolellis, et al., (2014) designed RabBit EscApe, a board game illustrated in Figure 5, to challenge students to orient tangible, magnetized manipulatives to complete or create paths. The game consisted of fourteen different shapes of wooden pieces that were half an inch thick; they were called bits. Each bit was equipped with small magnets, which were encased on different sides of the bit. As a result, the bits could attract or repel each other depending on polarity. The game's objective was to bring the bits together (matching opposing polarity) on the predefined path to help the rabbit escape from the fierce apes (separate pieces that needed to be repelled from the path). The research findings showed a positive outcome and that students learned the necessary computational thinking skills. The study of Apostolellis, et al., (2014) doesn't address computational thinking assessment explicitly; however, their study engages students in an escape game that covers most of the computational thinking components. The study ended on the note that there is a need to further develop the evaluation of their unplugged board game activity to understand the impact better.

Figure 5: RabBit EscApe (Apostolellis, et al., 2014)

Pandemic: Berland & Lee (2011) examined the idea of using contemporary strategic board games to teach computational thinking skills. They conducted a study on three groups of novice players using Pandemic, a board game illustrated in Figure 6, where players have to fight against infections that are spreading in various cities by collecting, sharing, and using the information to win the game. They analyzed the responses of players in the five elements of computational thinking, which include conditional action (deciding on the best moves to win the game), algorithm building (devising a plan of action), debugging (identifying errors based on moves taken), simulation (using hypothesis to test possible outcomes) and distributed computing (information sharing by different players while strategizing based on rule-based plan). Berland & Lee (2011) ended the paper on the note that board games could positively contribute by helping students develop computational thinking skills; however, further research is needed.

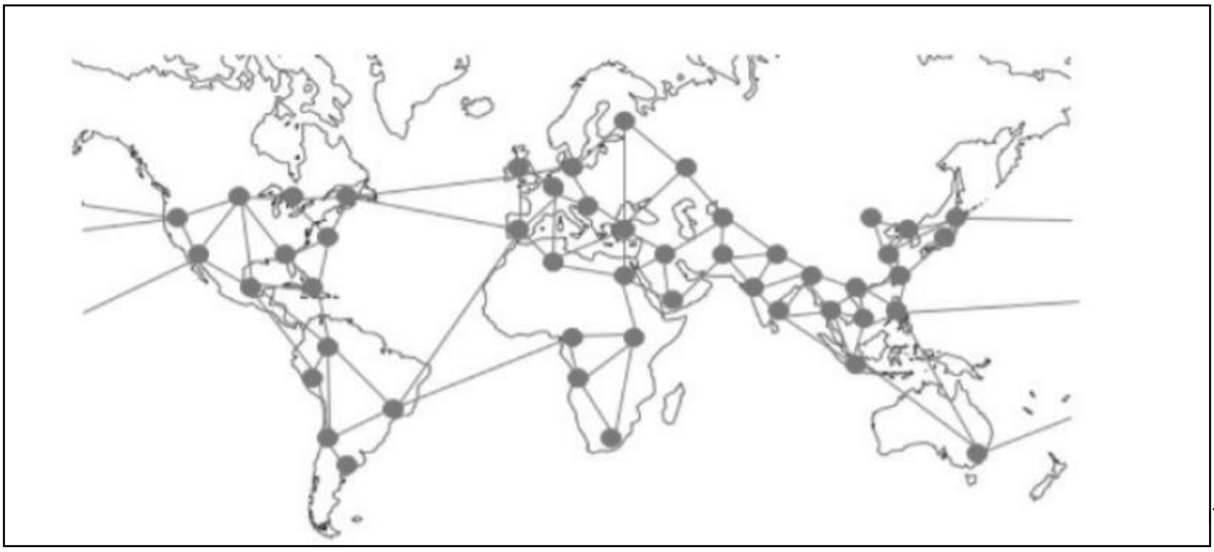


Figure 6: Pandemic (Berland & Lee, 2011)

T-Maze: Wang, et al.,(2014) conducted a study on several children around the age of 8 with prior knowledge of computers but without any prior programming experience. They used T-Maze, a physical programming tool illustrated in Figure 7, for children between the ages of 5 to 9 to play multi-level maze escape games and build their mazes by tinkering with some wooden blocks. They connected the wooden blocks, some of which were equipped with magnets and others with sensors, to either move a virtual avatar on the screen to escape from a maze (using the sensor blocks) or build a new maze by recreating a maze map and passable paths. There was no time limit given to students to complete the tasks. The study showed that students could learn concepts of abstraction, automation, problem decomposition, analysis, and creativity. The authors also specified that enhancing students' understanding of computational thinking was possible.

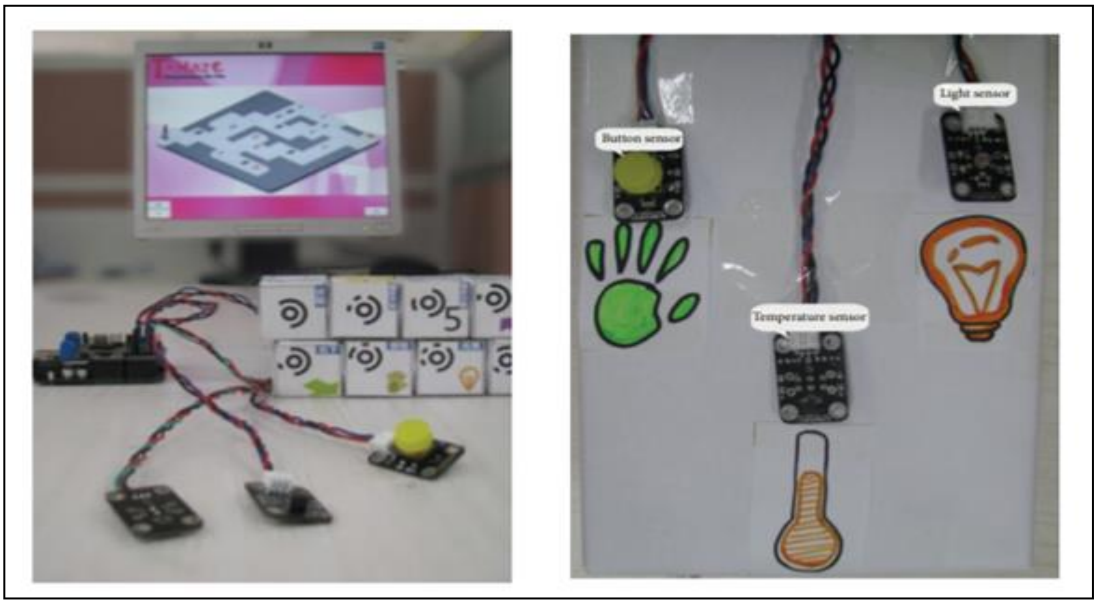


Figure 7: T-Maze (Wang, et al., 2014)

Program your Robot: Kazimoglu, et al., (2012) proposed an innovative game called "Program your Robot," illustrated in Figure 8, to develop students' computational thinking skills. The objective of the game is to assist a robot and help him escape from a series of platforms using an escape plan called a solution algorithm. Players constructed their solution algorithms by giving various commands to the robot to perform. These commands consisted of action (forwards, backward, left, and right) and programming (loops, decisions) commands and were dragged from their toolbars and dropped into specific areas called slots. The study showed that this approach could enhance the problem-solving abilities of students learning introductory computer programming.

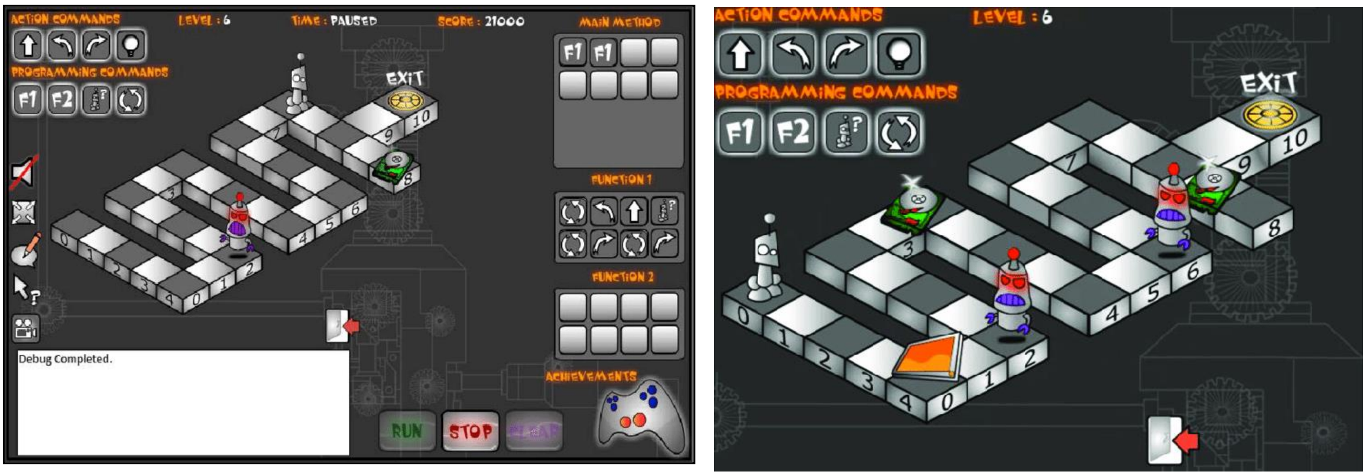


Figure 8: Program your Robot (Kazimoglu, et al., 2012)

CTArcade: Lee, et al., (2014) created a game called CTArcade, illustrated in Figure 9, a web-based educational gaming environment that extends simple games with scaffolded learning activities to assist children in developing computational thinking skills. Players must design a set of rules executed by a character while playing Tic-Tac-Toe. The authors observed a total of 18 students while they were playing Tic-Tac-Toe on CTArcade and paper. The study showed that children articulate more computational thinking skills using CTArcade compared to playing on paper. However, the analysis was carried out on Tic-Tac-Toe only, a pervasive and popular game; therefore, computational thinking was challenging to externalize and observe.

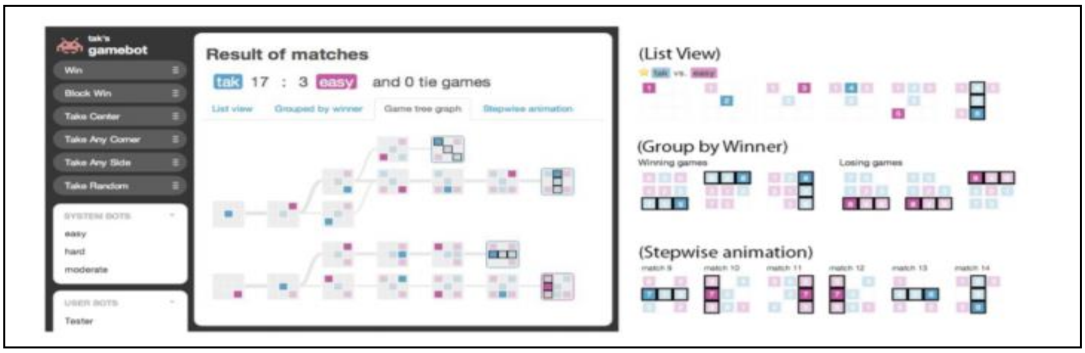


Figure 9: CTArcade (Lee, et al., 2014)

According to Nicholson (2015) and Clarke, et al., (2017), there are certain characteristics that define a game as an escape room game:

Nr.	Characteristic
1	Game based on adventure or fantasy
2	Based on theme of escape or rescue
3	Solving challenges/puzzles using resources within the game
4	Specific time limit
5	Team-based
6	Cooperative rather than competitive
7	Accomplishing a specific goal of escape or rescue
8	Strategizing moves that impact game outcomes
9	Learn by doing

Table 2: Characteristics of Escape Games (Nicholson, 2015; Clarke, et al., 2017)

From the list of games mentioned above, Menon, et al., (2019) concluded that only three games met the characteristics of an escape room game as defined by Nicholson (2015) and Clarke, et al., (2017), which include: RaBit EscAPE game, Pandemic board game, and T-Maze game. Each of the three games met six or more characteristics of an educational escape room game, as presented in Table 1. For example, in the RaBit EscAPE game, Apostolellis, et al., (2014) used the theme of helping rabbit tokens escape from enemy ape tokens to engage learners with the computational thinking topic. While Pandemic has not been proposed as an escape game by Berland & Lee (2011), it was included since it also meets most of the requirements of an escape game. Lastly, the T-Maze game presented by Wang, et al., (2014) also uses concepts of escaping from a maze.

From the above, it is clear that various types of initiatives exist to support the development of computational thinking through educational escape games; however, according to Makri, et al., (2021), very little research has been carried out to explore the impact of how virtual escape rooms can be used to facilitate computation thinking and whether the use of virtual escape rooms is a suitable method to teach computational thinking. Based on the studies mentioned above, it is clear that virtual escape rooms are innovative, promising, immersive, active, and collaborative instructional approaches that can guide and shape learning achievements. However, according to Lathwesen & Belova (2021), there are still various obstacles regarding virtual escape rooms that need to be addressed to fully make use of their potential. One such obstacle is the need for practical design frameworks. There is still a need for frameworks, methodologies, or guidelines aimed at virtual escape rooms to help educators not only create these new learning environments but also in developing design dispositions that will help them to adapt to the complexity of teaching in the 21st century (Lathwesen & Belova, 2021). As this study aims to investigate how to use virtual escape rooms to facilitate computational thinking, existing escape room frameworks were considered. However, only one framework, namely that of Clarke et al., (2017), was found and discussed below. The framework of Clarke et al., (2017), was chosen because it includes all components necessary for an educational escape room, unlike the other frameworks that only focussed on the escape room and not necessarily the educational aspects.

2.4 THE ESCAPED FRAMEWORK FOR CREATING EDUCATIONAL ESCAPE ROOMS

Clarke, et al., (2017) developed a potential framework for creating educational escape rooms, referred to as the escapED framework; however, the framework was solely aimed at physical escape rooms. The framework was created due to the recent entertainment trends of escape rooms to assist educational facilities and other interested parties in developing their escape rooms for educational purposes (Clarke, et al., 2017). Figure 10 below shows a graphical presentation of the framework.

Figure 10: EscapED Framework (Clarke, et al., 2017)

The framework consists of six areas: Participants, Objectives, Theme, Puzzles, Equipment, and Evaluation. These areas are further broken down into specific segments needed to create an educational version of an escape room (Clarke, et al., 2017). Each of these segments is discussed in more detail below:

Participants: The first step of the escapED framework involves developers conducting a user assessment, including details such as the target audience. Analyzing the target audience early in the process is considered conventional practice in most disciplines and common for entertainment game companies. The Participants' step is broken down into five sub-areas :

- User Type – Analysis of player demographic and educational needs;
- Time – Length of Escape Room Experience;
- Difficulty – Consideration of intended users to scale difficulty of puzzles for different levels of players;
- Mode – Analysis of mode of experience such as Cooperation based or Competitive based;
- Scale – Choosing the number of participants the game is designed for. This step will provide a detailed understanding of the user types – who will interact with the proposed game and how to proceed with the next development steps.

Objectives: The second part of the escapED framework involves developing the learning objectives for the escape room experience. According to Arnab & Clarke (2016), developing the learning objectives early on in the game guarantees that the escape room is designed purposefully. It also ensures that the game's theme and puzzles are developed to enhance the objectives rather than embed them into an already-designed game. The Objectives step is broken down into four sub-areas:

- Learning Objectives / Behavioural Change Objectives – Learning objectives is necessary in order to create a meaningful educational game. The objectives can be worked into various aspects of the game such as the theme, its puzzles and chosen mode to help structure the learning outcomes. Creating tangible objectives enables the developer to develop the evaluation strategy with the focus to access players learning experience, learning achievements, change metrics and can be iteratively re-designed to focus on the desired outcomes of the experience;

- Solo/Multi-Disciplinary: Deciding on one discipline or multiple disciplines;
- Soft Skills – Interactive live-action games can aid development of soft skills such as communication and leadership;
- Problem-Solving – Developing problem-solving challenges to make the game interesting for players. Following this step will provide a clear direction of what the objectives are that the game is trying to achieve with the participants. This will also provide the basis for developing the evaluation strategy later on in the design process.

Theme: The third step of the escapED framework is for developers to consider the overall theme of the experience. This step involves considering the player's motivations, game story, and content to bring a compelling game experience for the players. The Theme step is broken down into four sub-areas:

- Escape Mode – Deciding on the mode of escape i.e escape a locked room in a set time; Mystery Mode – Solve mystery in a set time;
- Narrative Design – Developing a compelling narrative for the game;
- Stand-alone/Nested – Determining whether the game is a one-off experience or part of a larger, nested experience in which several games can be designed and played.

Within the four steps, the developers need to consider the composition and narrative structure of the game so that the players can identify with the game experience and build personal motivations to complete the game.

Puzzles: The fourth step of the escapED framework involves developing puzzles and activities with which the players will interact during the game. The puzzles are designed by using the information obtained in the previous steps. The Puzzles step is broken down into four sub-areas:

- Puzzle Design – Designing the puzzles and riddles to make the game experience more interesting and tailoring it to fit the learning objectives;
- Reflect Learning Objectives – Ensuring that the puzzles reflect the overall goals of the game; Instructions / Manuals – Developing clear, set instructions and rules to help guide players;
- Clues/Hints – Developing the clues that can be used throughout the game. The objective of this step is to ensure that the puzzles reflect the objectives as set in the previous steps. This will allow for easier validation and assessment of whether the objectives have been achieved.

Equipment: The fifth step of the escapED framework involves deciding on the location/equipment used throughout the game to support the game experience. The Equipment step can be broken down into four sub-areas:

- Location/Space Design – Ensuring that enough space is available for the game experience so that it is comfortable to move around. The environment should reflect the theme as realistic as possible;
- Physical Props – Deciding on what props to use throughout the game to make a compelling and workable experience;
- Technical Props - Deciding on technology to enhance the game experience. Computers, VR, Augmented Reality, GPS and location-based identification can enhance the learner experience, however, there is a higher risk of things that can go wrong;
- Actors – Deciding on actors to help concrete the experience further as believable. Actors can be used as timer indicators or can give out hints if players get stuck.

This step is used to bring animation to the game experience in terms of providing a believable setting for the players to interact with.

Evaluation: The sixth and final step of the escapED framework is to consider how the game experience will be evaluated. Tied closely with the design considerations of the second step: Objectives, the developers have to consider the methods they will employ to assess whether the game has met the intended learning objectives and outcomes. The Evaluation step is broken down into five sub-areas:

- Testing – Test and iterate the game experience before playing a live session with intended participants; Reflection – Reflect with the players on their views and experience;
- Evaluate Learning Objectives – Creating formal evaluation that can be used to evaluate the learning objectives that were set for the game experience;
- Adjust – Use player feedback to decide on how adjustments of the game experience are going to be made;
- Re-set – Create a sheet that needs to be checked over to ensure everything is in the correct state before another play-through.

This step is used to inform the process of gathering data and to assess the overall efficiency and impact of the projects' transfer of knowledge.

2.4.1 The implementation of the escapED framework

The escapED framework has guided various studies in the creation of escape rooms. In a study by Löffler et al., (2021), an escape room was developed to raise awareness about cybersecurity (see Figure 11). The purpose of the study is to elaborate on the transformation of the physical game into a virtual learning experience to increase flexibility in times such as the Covid-19 lockdown. The escapED framework was used to guide the study. Evaluation results revealed positive results in that 80% of the students responded either "OK," "Good," or "Great" on their evaluation form.

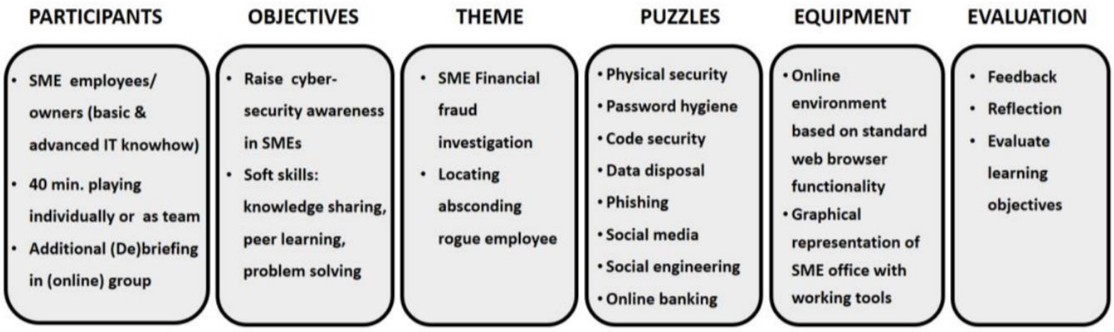


Figure 11: CySecEscape 2.0 prototype design

Tzima et al., (2021) developed a challenging escape game about the local cultural heritage, where players had to solve riddles about the cultural asset of watermills (see Figure 12). The game, MillSecret, was developed based on the escapED framework and AR technology. Evaluation results revealed that the game experience delivered positive effects and offered players multiple valuable benefits such as new knowledge, teamwork, collaboration, enjoyment, motivation, etc. The above benefits correspond to other surveys' learning outcomes, enhancements, and improvements.

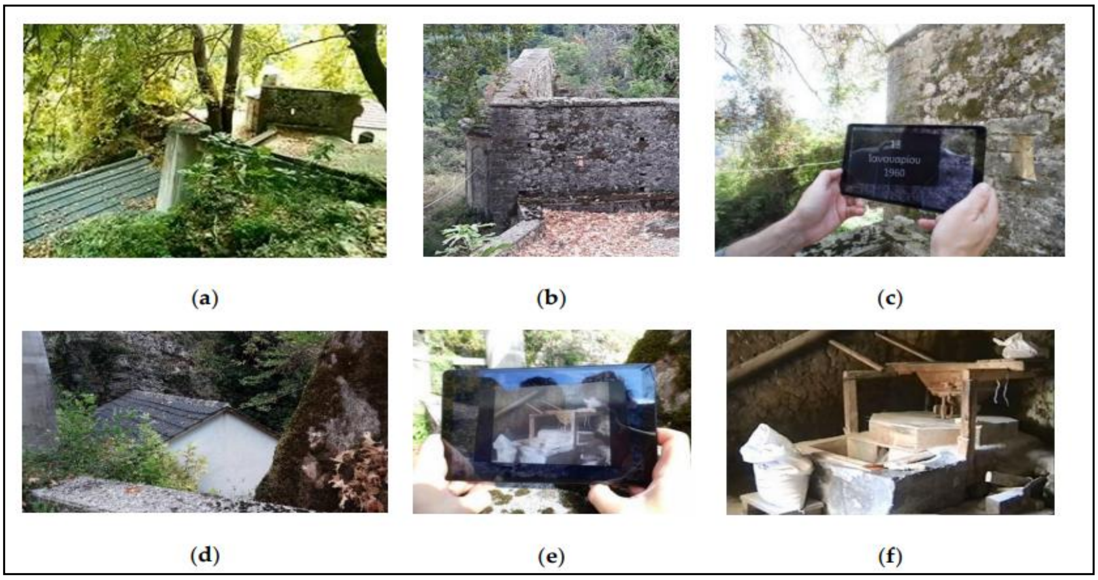


Figure 12: Game Experience

Bartzia & De Smet (2019) conducted a game-based learning approach to teach mathematics to unaccompanied minors. The study presented the conception and the realization of a serious game whose first objective is the discovery of different domains of mathematics by problem-solving and developing logical skills. The game is based on the escapED framework and has been designed explicitly for unaccompanied migrant children, considering cultural, linguistic, and technological barriers. It targets decreasing their isolation and exclusion by including different cultural and geographical elements.

The escapED framework presented in this section is a theoretically informed methodology for educational facilitators and other interested parties who wish to create their educational escape rooms and live interactive game experiences within higher education settings. This framework also serves as the basis for the suggested framework discussed in Chapter 4.

2.5 CONCLUSION

Game-based learning has become a very effective tool for education because numerous studies have supported its positive effects on learning. More and more students prefer game-based learning approaches over traditional approaches. One popular game-based learning initiative that has taken education by storm is escape rooms. Various attempts have been made surrounding the use of escape games in computational thinking development; however, in most cases, there is a lack of published literature on the activity, its evaluation methods, and the data to support its effectiveness. The study conducted by Menon, et al., (2019) shows that various papers have been published on escape games and computational thinking; however, the majority of the games do not classify as escape room games, and within the three games that have met the criteria, there is a lack of data to support the effectiveness. Vidergor (2021) believes there is potential in virtual escape rooms. As a result of the lack of published papers surrounding the use of virtual escape rooms in the teaching of computational thinking, the researcher believes there is an opportunity to expand the current knowledge by providing a framework for the use of virtual escape rooms in the facilitation of computational thinking.

3 METHODOLOGY

3.1 INTRODUCTION

In this chapter, the researcher strived to align the methodological choices with the research questions and the purpose of this study. This chapter commences with a brief restatement of the purpose of the study, followed by a theoretical overview of the research process, which includes: research philosophy, research strategy, data collection methods, and data analysis methods. After that, the research philosophy, strategy, data collection methods, and analysis methods that guided this study are discussed. The chapter concludes with the ethical considerations that guided the research design and practices in the study.

3.2 PURPOSE OF THE STUDY

The study explores the use of virtual escape rooms as a teaching method for computational thinking. The researcher was guided by the following research questions presented in Table 1:

Main Research Question	What are the components of a framework guiding the use of virtual escape rooms in the teaching of computational thinking?
Sub-Research Questions	What are the benefits of virtual escape rooms used in education?
	How are virtual escape rooms used in education?
	How can the use of virtual escape rooms develop computational thinking skills?

Table 3: Research Questions

3.3 RESEARCH PURPOSE

The research process refers to the actions necessary to effectively carry out research (Saunders, et al., 2020). The research model utilized in this chapter is that of Oates (see Figure 13 for more detail). Oates (2006) described the research process as consisting of the following components: personal experiences and motivation, literature review, research questions, conceptual framework, strategies, data generation methods, and quantitative and qualitative data analysis.

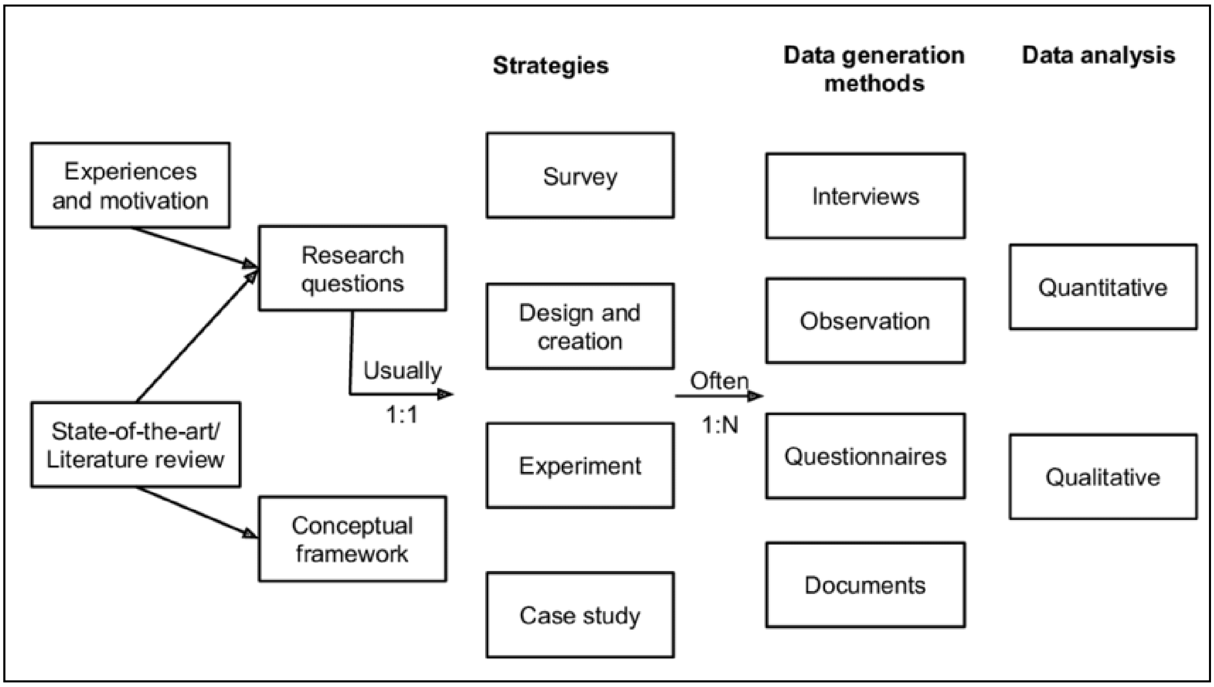


Figure 13: Model for Research Process (Oates, 2006)

The research motivation, literature review, research questions and conceptual framework have already been described in Chapters 1 and 2. The strategies, data generation, and data analysis methods that were utilized in the study to collect the data will be described in the chapter below.

3.4 RESEARCH PHILOSOPHIES

Philosophy is concerned with the different views within the world and the processes that operate within it. It focuses primarily on reality, knowledge, and existence (Mason, 2014). According to Saunders, et al., (2020), it is essential for researchers to understand the nature of reality, what can be known about it and how we can attain knowledge. Considering research philosophy, all research is based on primary assumptions of what methods are suitable and what constitutes binding research (Myers, 1997). Philosophical assumptions can be described in the following four categories:

3.4.1 Philosophical Assumptions

Ontological assumptions: Describe the nature of reality and its characteristics. Researchers have certain assumptions about reality, how it exists and what can be known about it. Ontology, therefore, aims to answer questions regarding the kind of realities that exist (Myers, 1997; Oates, 2006).

Epistemological assumptions: Describe the nature of knowledge and the process by which knowledge is acquired and validated. Epistemology, therefore, aims to answer questions regarding what constitutes acceptable, valid, and legitimate knowledge and how we communicate that knowledge to people (Myers, 1997; Oates, 2006).

Axiological assumptions**:** Describe the study of human values, primarily the relationship between human beings and their environment. Axiology, therefore, aims to answer questions regarding what values an individual holds and why (Myers, 1997; Oates, 2006).

Methodological assumptions*:* Describe the methods used in the research process, i.e., how the researcher investigates and acquires knowledge concerning the research subject (Myers, 1997; Oates, 2006).

3.4.2 Research Paradigms

Philosophies have different underlying philosophical paradigms. A paradigm refers to a set of shared assumptions or ways of thinking about some aspect of the word (Saunders, et al., 2020). The following four paradigms will be discussed in more detail below: positivism, interpretivism, pragmatism, and postmodernism.

Positivism: The positivist paradigm is known as the scientific method of investigation; it, therefore, assumes that reality is presented objectively and can be described by measurable properties independent of the researcher. Research in this paradigm usually relies on deductive reasoning, formulating hypotheses, testing hypotheses, operational definitions and mathematical equations, calculations, extrapolations, and expressions, to derive conclusions. As a result, it assumes a single truth that resides in a regularly ordered world (Myers, 1997; Oates, 2006; Orlikowski & Baroudi, 1991; Kivunja & Kuyini, 2017).

Interpretive: The interpretive paradigm is grounded on understanding the subjective world of human experience; in other words, access to reality is only through social constructions such as language, consciousness, and shared meanings. Interpretive studies allow the researcher to understand experiences, rather than predicting experiences, by getting into the head of the subjects being studied to understand and interpret what the subject is thinking or the meaning he/she is making of the context. Every effort is made to understand the viewpoint of the subject being studied rather than the researcher's viewpoint (Oates, 2006; Myers, 1997; Kivunja & Kuyini, 2017).

***Pragmatism*:** Pragmatists argue that it is impossible to access the truth by relying solely on a single scientific method, as advocated by the Positivist paradigm, nor through the social reality as constructed under the Interpretivist paradigm (Kivunja & Kuyini, 2017). Instead, a worldview is required to provide the methods most appropriate for studying the phenomenon at hand (Alise & Teddlie, 2010; Biesta, 2010; Kivunja & Kuyini, 2017). Pragmatists consider more practical and pluralistic approaches that allow for a combination of methods that, in conjunction, could shed light on the actual behavior of the participants, the beliefs that stand behind those behaviors, and the consequences that are likely to follow from different behaviors (Kivunja & Kuyini, 2017).

Postmodernism: Postmodernism emphasizes the role of language and power relations, in other words, seeking to question accepted ways of thinking and give voice to marginalized alternative views. Postmodernists go further than interpretivism when it comes to their critique of positivism and objectivism, attributing even more importance to the role of language. Modern objectivist and realistic ontology are some of the few points that postmodernist rejects; instead, the emphasis is placed on the chaotic primacy of flux, movement, fluidity, and change (Saunders, et al., 2009; Saunders, et al., 2007; Zukauskas, et al., 2018).

Table 4 exhibits a summation of the different philosophical assumptions (ontology, epistemology, axiology and methodology) with respect to their research paradigms (positivism, interpretivism, pragmatism and postmodernism):

Philosophical Assumption	Positivist	Interpretivist	Pragmatist	Postmodernist
Ontology	• Single stable reality • Law-like	• Multiple realities • Socially constructed .	• Multiple views • External • View chosen to best answer the researcher question	• Nominal Complex, rich. • Socially constructed through power relations. • Some meanings, interpretations, realities are dominated and silenced by others. • Flux of processes, experiences, practices
Epistemology	• Objective • Dethatched observer	• Empathetic • Observer subjectively	• Both observable and subjective • Focus on practical applied research • Integrate different perspectives to assist with interpreting the data	• What counts as 'truth' and 'knowledge' is decided by dominant ideologies • Focus on absences, silences and oppressed/ repressed meanings, interpretations and voices • Exposure of power

				relations and challenge of dominant views as contribution
Axiology	• Truth (Objective) • Prediction	• Contextual understanding • Researcher's objective values	• Values play a large role in interpreting the results • Adopting both objective and subjective point of views	• Value-constituted research • Researcher and research embedded in power relations • Some research narratives are repressed and silenced at the expense of others • Researcher radically reflexive •
Methodology	• Experimental • Quantitative • Hypothesis Testing	• Interactional • Interpretation • Qualitative	• Qualitative and Quantitative • Experimental and Interactional	• Typically, deconstructive – reading texts and realities against themselves • In-depth investigations of anomalies, silences and absences • Range of data types, typically qualitative

				methods of analysis

Table 4: Philosophical assumptions and research paradigms

3.5 RESEARCH STRATEGIES

Oates (2006) defines a *research strategy* as an overall approach to answering the research question. The selection of the research strategy will be guided by the research questions, the extent of existing knowledge, the amount of time and other resources available, and the researcher's philosophical underpinnings (Saunders, et al., 2020; Oates, 2006).

3.5.1 Types of research strategies

Survey: Surveys refer to how information is collected from a sample of individuals through responses to questions. It allows researchers to use multiple methods to recruit participants, collect data and utilize various instrumentation methods (Ponto, 2015). Surveys can contain quantitative (e.g., questionnaires with numerically rated items) and qualitative (e.g., open-ended questions) or both types of questions. It is usually associated with deductive reasoning and is considered an effective way to collect a large amount of data from a sizable population in a highly economical way. Typical survey questions are the who, what, where, how much, and how many questions (Oates, 2006; Ponto, 2015).

Design and Creation: The concept of design and creation involves the development of new artifacts. According to Oates (2006), the strategy utilizes an iterative process containing five steps: awareness (stating a problem), suggestion (expression of the design idea), development (implementing the design idea), evaluation (assessing the artifact), and conclusion (consolidating and documenting the results and knowledge of the design process) (Oates, 2006).

Experiment: Oates (2006) defines an *experiment* as a strategy that investigates two factors: (1) cause-and-effect relationships and (2) proving or disproving a causal link between a factor and an observed outcome (Oates, 2006). It is a classical research strategy often used within the natural sciences. An experiment involves the definition of a theoretical hypothesis, a variable that the researcher can manipulate, and variables that can be measured. More straightforward experiments are concerned with whether there is a link between two variables, while the more complex experiments are concerned with the size, the change, and the relative importance of two or more independent variables. An experimental researcher is usually well-versed in using statistical tools and techniques (Oates, 2006; Saunders, et al., 2020).

Case Study: A case study involves an empirical investigation of a particular issue within a real-life context using multiple sources of evidence. The strategy differs from experimental research, undertaken within a highly controlled context. It also differs from survey research since the ability to explore and understand the context is limited by the number of variables for which the data is collected (Oates, 2006; Saunders, et al., 2020).

Oates (2006) defines three basic types of case studies: exploratory, descriptive, and explanatory. Exploratory case studies define questions or hypotheses within the study. They assist the researcher in understanding the research problem and are instrumental when there is not enough information in the literature about a topic allowing for a real-life instance to be investigated (Oates, 2006). Descriptive case studies provide a rich, detailed analysis of a particular phenomenon and its context. The analysis tells a story, including discussions of what occurred and how different people perceived what occurred (Oates, 2006). An explanatory study goes further than a descriptive study by explaining why events or particular outcomes occurred (Oates, 2006).

Action research: Action research is an interventionist approach to acquiring scientific knowledge. It can be explained in two simple steps: (1) the diagnosis and analysis of the situation by which a hypothesis is formulated, and (2) the performing of change experiments in a collaborated manner whereby the effects are studied. This strategy allows the researcher to get involved in the study and influence the research itself (Oates, 2006; Baskerville & Wood-Harper, 1998).

Ethnography: Ethnography has its roots in anthropology. It involves studying people in their natural environment, in effect, studying cultures. The process is very time-consuming, and the researcher needs to be very flexible and responsive to change since the researcher will constantly develop new patterns of thought about what is being observed (Oates, 2006; Saunders, et al., 2020)

3.6 DATA COLLECTION METHODS

The data collection process involves gathering and measuring information on variables that enables the researcher to answer the research question, test hypotheses, and evaluate outcomes. The process is utilized in all fields of study, including physical and social sciences, humanities, business, and many more. The data collection process aims to capture quality evidence translated into rich data analysis to build more convincing and credible answers to the research questions (Hinojosa, et al., 1994). The data collection process starts with defining the data that needs to be collected. Data can be categorized into two main categories: qualitative and quantitative. Each category will be explained in more detail below:

3.6.1 Types of Data

Qualitative*:* Qualitative data refers to any data collection or analysis techniques that produce or use non-numerical data, including images and videos (Saunders, et al., 2020). It may also include data such as feelings, emotions, or subjective perceptions of something (Hinojosa, et al., 1994). Qualitative data aims to address the "how" and "why" and tends to use unstructured data collection methods to explore the topic thoroughly. Qualitative questions are usually open-ended and include focus groups, group discussions, and interviews (Hinojosa, et al., 1994).

Quantitative: Quantitative data are numerical and can be mathematically computed. It concerns testing hypotheses derived from theories or estimating the size of a phenomenon or interest. It relies on random sampling and structured data collection instruments that categorize diverse experiences into predetermined response categories (Hinojosa, et al., 1994). The results resulting from the data are easy to summarize, compare and generalize (Hinojosa, et al., 1994).

Once the type of data has been established, the next step is to select the sample from which the data will be collected. Since the researcher neither has the time nor resources to collect and analyze the data from an entire population, specific sampling techniques will be applied to select the sample that would benefit the research.

3.6.2 Sampling Techniques

There are various types of sampling techniques that can be applied. Each technique will be discussed in more detail below:

Probability sampling techniques (Taherdoost, 2016)**:**

- **Simple random sampling** - every case of the population has an equal probability of inclusion in the sample.
- **Systematic sampling** – where every nth case after a random start is selected, for example, if surveying a sample of consumers, every fifth consumer may be selected for the sample.
- **Cluster sampling** – where the whole population is divided into clusters or groups. A random sample are taken from these clusters, all of which are used in the final sample.
- **Multi-stage sampling** – involves a process of moving from broad to narrow sample using a step by step process.

Non-probability sampling techniques (Taherdoost, 2016):

- **Quota sampling** – participants are chosen on the basis of predetermined characteristics so that the total population all have the same distribution of characteristics.
- **Snowball sampling** – uses a few cases to help encourage other cases to take part in the study, thereby increasing the sample size.
- **Convenience sampling** – participants are selected as part of the sample because they are often readily and easily available.
- **Purposive sampling** – participants are selected deliberately in order to provide information that cannot be obtained from other sources, in other words, the researcher selects participants that would advance the purpose of the study.

Once the sample technique has been selected, the researcher needs to define what type of data collection methods will be used to collect the data from the selected sample.

3.6.3 Data Collection Methods

Once the type of data and the sample has been established, the next step is to determine what type of method will be used to collect the data from the selected sample. Oates

(2006) identifies the following data collection methods: interviews, questionnaires, observations and documentations.

Interviews: *Interviews* are defined as a conversation that occurs between people who have a set of assumptions. Researchers use them to obtain reliable and valid data relevant to the research questions and objectives. Unlike "normal" conversations, interviews involve discussions that the researcher plans. This implies that there is no free-flowing form of conversation like with other conversations; instead, there is a tacit agreement that the researcher has the right to control both the agenda and proceedings and will ask the majority of the questions. Interviews are divided into three types: structured, semi-structured, and unstructured (Oates, 2006; Denzin & Lincoln, 2017; Silverman, 2019):

- Structured interviews involve pre-determined, standardized, and identical questions;
- Semi-structured interviews involve a list of themes that are covered during the interview;
- Within unstructured interviews, the researcher has less control. The researcher starts by introducing the topic allowing the interviewee to develop their ideas and steer the conversation.

Observation: To observe means to "watch" and to "pay attention. Observations are about what people do rather than what they report they do. Most often, observations are confined by interpretations of sight only, but there are some scenarios in which other senses may be involved, like sight, hearing, smelling, touching, and tasting (Oates, 2006; Denzin & Lincoln, 2017; Silverman, 2019). Two distinctive types of observation exist: covert and overt. The first, called "covert," involves observations done without the participants' knowledge and consent. The second, called "overt," involves observations done with the participants' knowledge and consent (Oates, 2006; Denzin & Lincoln, 2017; Silverman, 2019).

Questionnaires: Questionnaires contain a pre-defined set of questions assembled in a pre-determined order to collect or generate data to be analysed. Questionnaires are frequently associated with survey research strategy because they are often sent out to a sample of people who are asked to complete and return it to the researcher. Once received, the researcher will typically analyze all the responses to identify any patterns to make generalizations about the actions or views of a larger population than the sample. A significant advantage of questionnaires is that they can be self-administrated or researcher–administrated (Oates, 2006; Denzin & Lincoln, 2017; Silverman, 2019). Self-administrated questionnaires involve the respondent completing the questionnaire without the researcher being present. Researcher-administrated questionnaires involve asking the respondent each question and then writing down the response (Oates, 2006; Denzin & Lincoln, 2017; Silverman, 2019).

Documents: Documents are an alternative to the other data collection techniques specified above. Documents can be generated by using both found documents as well as researcher-generated documents. Found documents exist before research, such as those found in most organizations: production schedules, profit and loss accounts, internal telephone directories, job descriptions, procedure manuals, and many more. Researcher-generated documents are put together solely for the research task and would not otherwise have existed (Oates, 2006) (Oates, 2006; Denzin & Lincoln, 2017; Silverman, 2019).

3.7 DATA ANALYSIS METHODS

The data analysis process commences after the data has been collected. It involves the researcher analyzing the data to look for any relationships or themes using the selected research strategy. Various types of data analysis methods exist for the two main primary data types, and each will be explained in more detail below:

3.7.1 Quantitative Data Analysis

Quantitative data analysis involves the analysis of numerical data. It is generally used for three purposes: (1) to measure the difference between groups, (2) to assess the relationship between variables, and (3) to test a hypothesis in a scientifically rigorous way. There are two main types of quantitative analysis methods that exist, and each will be explained in more detail below:

Descriptive statistics: Descriptive statistics focuses on describing the data set to help understand the details of the sample (Jansen & Warren, 2020). Some standard statistical tests used under this type of method include the following (Jansen & Warren, 2020):

- **Mean** – the mathematical average of a range of numbers.
- **Median** – the midpoint in a range of numbers when the numbers are arranged in numerical order.
- **Mode** – the most common occurring number in a data set
- **Standard deviation** – the metric indicates how dispersed a range of numbers is, in other words, how close all the numbers are to the mean.
- **Skewness** – skewness indicates how symmetrical a range of numbers is.

Inferential statistics: Inferential statistics involves making predictions about what the researcher would find in the entire population (Jansen & Warren, 2020). There are two types of predictions that a researcher can make using inferential statistics: (1) predictions about differences between groups and (2) predictions about the relationship between variables (Jansen & Warren, 2020). There are various types of statistical analysis methods that exist, and each will be explained in more detail below:

- **T-test** – compare means of two groups of data to assess whether they are significantly different.
- **ANOVA** – similar to t-tests but instead of analysing two groups it enables the researcher to analyse multiple groups.
- **Correlation analysis** - to assess the relationship between two variables, in other words, if one variable increases, does the other variable also increase, decrease or stay the same.
- **Regression analysis** – similar to correlation analysis in that it assesses the relationship between variables, but it goes a step further to understand the cause and effort.

3.7.2 Qualitative Data Analysis

Qualitative data analysis focuses on words, descriptions, concepts, or ideas. Various qualitative data analysis methods exist; each will be explained in more detail below (Jansen & Warren, 2020):

- **Qualitative content analysis** – to evaluate patterns within a piece of content or across multiple pieces of content or sources of communication.
- **Narrative analysis** – to listen to people telling stories and analysing what that means.
- **Discourse analysis** – to analyse language within a social context.
- **Thematic analysis** – to look at patterns of meaning within a data set. It takes bodies of data and groups them according to similarities in order to make sense of the content and derive meaning from it.
- **Grounded theory** – to create a new theory using the data at hand through a series of tests and revisions.
- **Interpretive phenomenological analysis** – to understand the personal experiences of a subject concerning a major life event, experience or situation.

3.8 RESEARCH DESIGN OF THIS STUDY

The previous sections provided background information on the different types of research philosophies, strategies, data collection methods, and analysis methods. Section 1.8 will describe the research design of this dissertation:

3.8.1 Research philosophy

The research philosophy that resonates most closely with this research is pragmatism because the researcher aims to create an artefact in the form of a framework for virtual escape rooms to teach computational thinking. To validate the framework, the researcher will rely on the results of the pre-and post-test and feedback obtained from interviews conducted with two senior university lecturers. Therefore, the ontological position is based on the underlying belief that the absolute truth cannot solely be extracted based on facts and figures but that a social context is also required.

The epistemological position is based on the belief that knowledge and meaning are gained through action. The researcher will, therefore, implement different cycles during the study where the framework will be implemented, tested, and adjusted until it achieves its goal.

The methodological position is based on the best methodology approach for the research problem. The researcher adopted a design-based method because it allowed the researcher to acquire knowledge through actions to solve the research problem. It also allowed the researcher to implement data collection and analysis techniques best suited for the research.

The axiological position is based on the fact that the researcher places great value on the research outcomes. Therefore, the researcher believes that if the framework is proven to be valid and effective, then the value of the research is proven to be good. The researcher also believes that computational thinking is essential and can be developed in students.

3.8.2 Sampling technique followed in the research

By using a design-based research strategy, the three cycles each have their own respective sampling techniques. Each of these techniques will be described in more detail below.

3.8.3 Research strategy

The research strategy that resonates most closely with the research is Design-Based research. Design-based research is defined as a research strategy that aims to improve education practices through systematic, flexible, and iterative review, analysis, design, development, and implementation in real-world settings, thus leading to design principles or theories (Wang & Hannafin, 2005). De Villiers & Harpur (2013) define design-based research as a series of approaches that aims to produce new theories, artifacts, and practices related to teaching and learning in natural settings, with the potential to be adopted elsewhere. By looking at the overall objective of the study, it supports the definition of design-based research as provided above because of the following: (1) the researcher aims to produce an artifact in the form of a framework through a series of iterative cycles consisting of analysis, design, development, implementation, and evaluation, and (2) the researcher aims to improve current educational practices regarding the teaching of computational thinking through the implementation of the framework.

Design-based research received a considerable amount of attention in education as an emerging framework that can guide better educational research (Baumgartner et al., 2003;

Brown, 1992; Cobb et al., 2003; Van den Akker et al., 2006). According to Reeves (2020), there are three cornerstone principles of design-based research:

1. Addressing complex problems in a real-world context.
2. Integrating design principles with technology advances to render plausible solutions to complex problems.
3. Conducting rigorous and reflective inquiry to test and refine innovative learning environments and define new design principles.

The ultimate goal of implementing design-based research is to build stronger connections between educational research and real-world problems. The emphasis is placed on an iterative research process that does not just evaluate a product or intervention but also attempts to refine the innovation and produce design principles that can guide similar research and development endeavours (Reeves, 2020). There are various models of the design research process: (1) the model used by van den Akker et al., (2013) that suggests that immediate outcomes relate to the results of an intervention or product within the cyclic process, and distant outcomes emerge when immediate outcomes lead to distant outcomes in the form of generalizable principles, and (2) the model proposed by Reeves (2000) that emphasizes the iterative interaction between researchers and practitioners to clarify problems and refine potential solutions in evolutionary prototyping. de Villiers (2005) proposed a generic model that is influenced by both the models of van den Akker et al., (2013) and Reeves (2000) (see Figure 14).

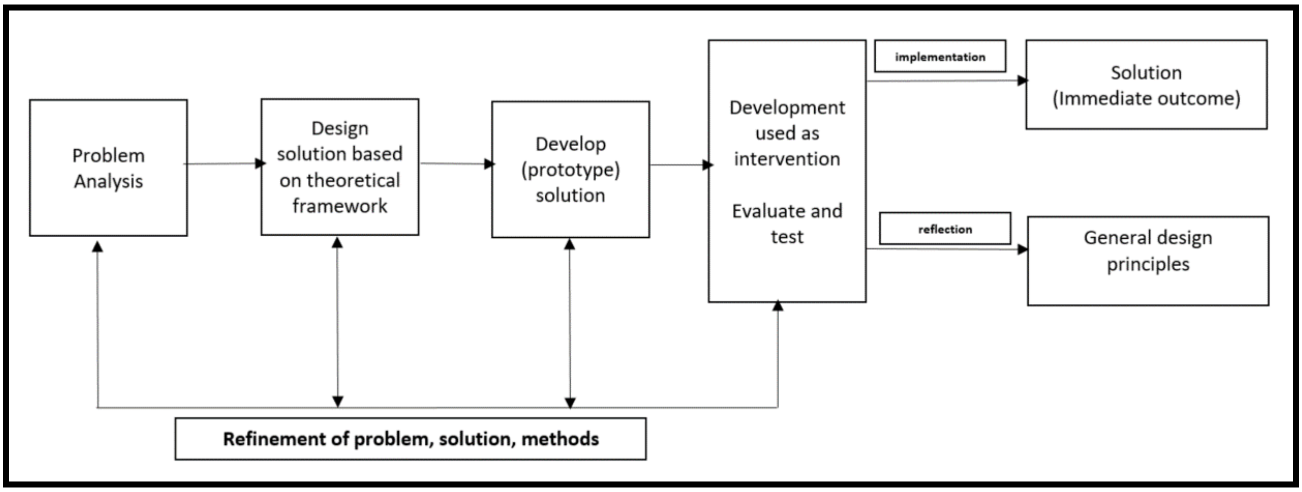


Figure 14: Development research model (van den Akker et al., (2013) and Reeves (2000))

Villiers & Harpur (2013) proposed a generic Design-Based Research model that is adapted from the model proposed by de Villiers (2005), showing the iterative design and research approach as a process in a natural context, progressing from the problem on the left to the solution on the right (see Figure 15). The model is based on the notation of the classic ADDIE Model: analyze, design, develop, implement, evaluate, and emphasize the need for rigor. The left side shows the initial complex problem and the need for innovation on which a pragmatic approach to the solution is based, while the right side indicates the synergy between practice and theory and between design and research. (Villiers & Harpur, 2013).

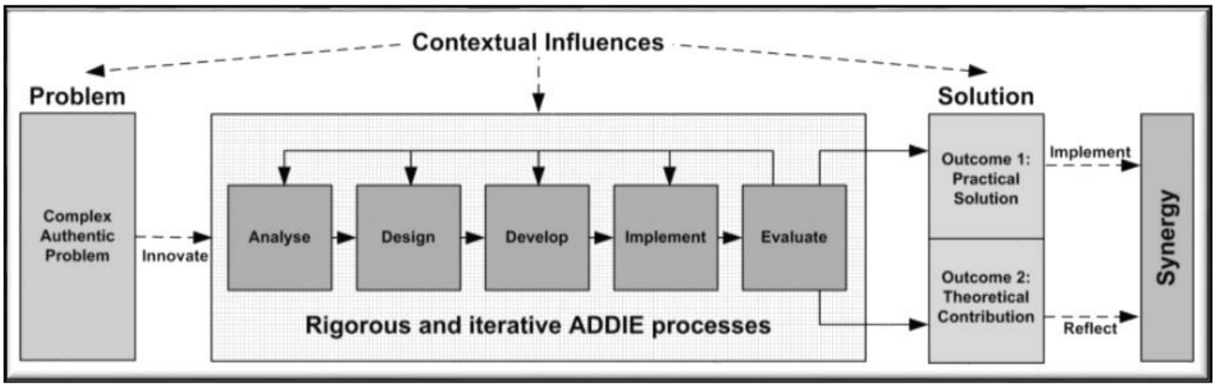


Figure 15: Generic Model of Design-Based Research Process within a Context (van den Akker et al., (2013) and Reeves (2000))

3.8.4 Design-based research model applied to this study

The study was conducted in three iterative cycles. The first two cycles used a case study (case study 1) to implement and evaluate the different versions of the framework. The second cycle data collection was focused on the two lecturers involved during the case study. The last cycle used another case study (case study 2), focused on the same course but different students. Figure 16 shows how this strategy was applied in this study. This will be discussed in more detail in the next section.

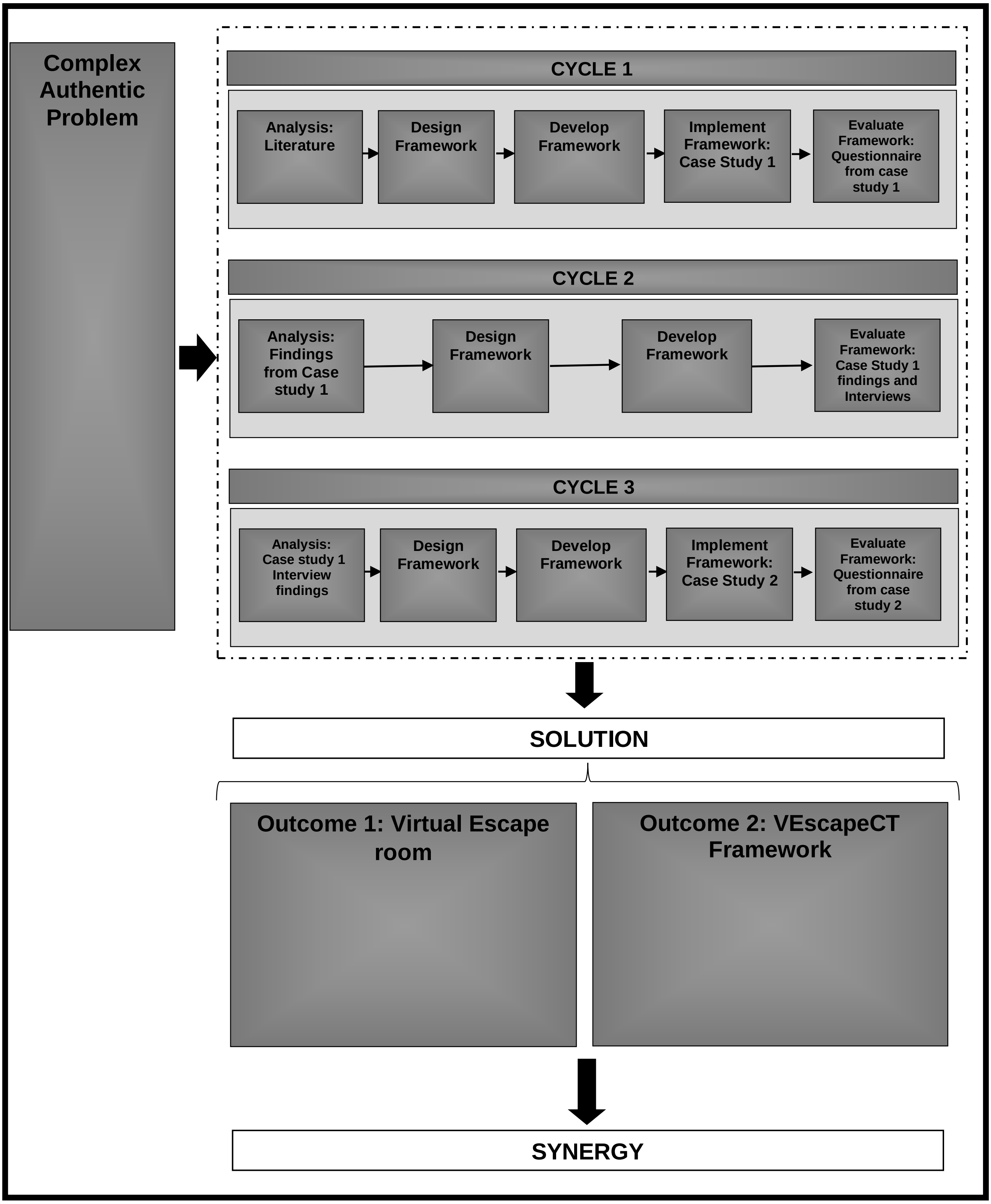


Figure 16: Design-Based Research Adapted from (Villiers & Harpur, 2013).

Each cycle is based on the notation of the classic ADDIE model: analyze, design, develop, implement, evaluate, and emphasize (see Figure 4). The ADDIE model is a generic instructional design model that guides various groups, such as instructional designers, software engineers, etc., as they author and revise learning products. The phases are sequential, meaning each depends upon the successful completion of the initial phase (Welty, 2007). The ADDIE model refers to a feedback model, which means that the results of the evaluation phase are returned to the origination point, thus closing the loop and facilitating further refinement of the learning product (Welty, 2007).

3.8.4.1. Cycle 1:

The first cycle allowed the researcher to explore how virtual escape rooms can teach computational thinking skills by implementing a virtual escae room in a real-life instance.

3.8.4.1.1. Analysis

The researcher started the research process by conducting a literature review to investigate computational thinking teaching practices. The researcher found multiple studies supporting game-based learning, specifically games with an escape theme as a teaching method. This led the researcher to investigate the use of escape rooms, more specifically virtual ones, as a possible teaching method for computational thinking. The researcher found a limited body of literature on the topic and has therefore implemented an exploratory case study to understand the topic in-depth. The choice of case study is based on Oates's (2006) assertion that exploratory case studies are instrumental when there is little in the literature on the topic, allowing for a real-life instance to be investigated. The exploratory case study allowed the researcher to investigate the possibility of using virtual escape rooms to teach computational thinking skills in a real-life instance and specific context.

3.8.4.1.2. Design the Framework

To explore the case described above, the researcher started with the design of the first version of the Virtual escape room framework for computational thinking (VEscapeCT). As part of the literature review study presented in Chapter 2, the researcher examined various frameworks that support the creation of educational escape rooms. The researcher identified one framework called the EscapED framework (see Figure 18). The EscapED framework consists of six elements: participants, objectives, theme, puzzles, equipment, and evaluation (Clarke et al., 2017) – see Figure 17. The researcher used this framework to base the first version of the virtual escape room framework on.

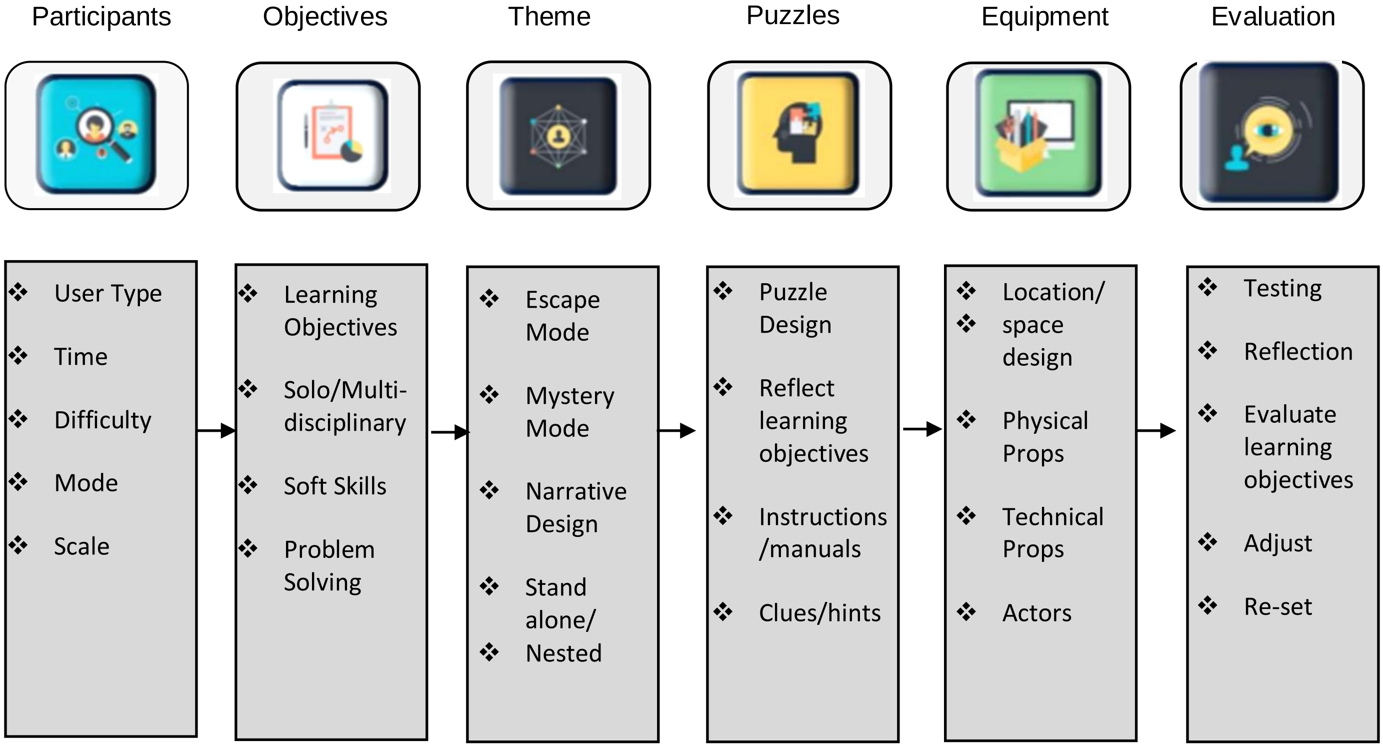


Figure 17: EscapED Framework (Clarke et al., 2017)

3.8.4.1.3. Develop the Framework

To evaluate the effectiveness of the framework identified in the previous section, the researcher developed a PowerPoint virtual escape room (to be discussed in more detail in the next section) as well as two sets of slides to (1) illustrate how the components of computational thinking were implemented in the virtual escape room and (2) demonstrate how computational thinking can assist with programming and a number of data collection instruments to obtain an in-depth exploration of how virtual escape rooms can be used to teach computational thinking skills. The instruments consisted of the following:

- Pre- and post-tests with the objective to test students' knowledge on computational thinking before and after the implementation of the virtual escape room (to be discussed in more detail in the implementation section)
- Evaluation form to determine how students experienced the learning process (to be discussed in more detail in the implementation section)

3.8.4.1.4. Implement the Framework

The implementation phase occurred in a case study setting (case study 1). The type of case study utilized is exploratory because the researcher explores a specific instance. The target population of the case study focused on first-year students from the Department of Informatics at the University of Pretoria, specifically students who struggled with programming and who attended the INF 154 (programming) winter school. The sampling technique that was applied by the researcher was convenience sampling because the group of students that attended the winter school was available to participate at the time. There were no inclusion criteria that was identified prior to the selection of the students, therefore, all the students were invited to participate. The sample size consisted of 15 students, which was not a sample size selected by the researcher, but the number of students that attended the INF 154 winter school. The researcher specifically selected these students because of their low marks to demonstrate how the implementation of the framework can assist in teaching problem-solving skills, such as computational thinking, that can help improve their marks.

3.8.4.1.5. Evaluation of the Framework

The evaluation phase involved the evaluation of the framework and the way it was implemented. Questionnaires were selected as the primary data collection tool, and descriptive statistics were used as the data analysis method.

Questionnaire Design

Pre and Post Test Questionnaires

As part of the literature review conducted in Chapter 2, the researcher identified various assessment tools for computational thinking. However, most of these assessment instruments aim to analyse programming projects in specific environments, such as Dr. Scratch (Zapata et al., 2021). By eliminating the assessment tools that are focussed on programming and that would not be beneficial for the study, the researcher was able to identify an assessment tool suitable for this study, which is diagnostic assessment instruments. Diagnostic instruments are defined as performance tests that do not require prior knowledge, and can be used to evaluate learning gains by comparing pre-and post-test results (Guggemos et al., 2022). One particular type of diagnostic assessment that has proven to be a valid and reliable form of assessment is the Computational Thinking Test (CTt). It consists of a multiple-choice instrument composed of 28 items administered online in a maximum time of 45 min (Guggemos et al., 2022). According to Kallia (2017), multiple-choice questions are one of the most applied types of assessment. Mindetbay et al., (2019) support this statement by stating that multiple-choice questions are the most suitable format for assessing higher-order cognitive skills and abilities, such as problem-solving, synthesis, and evaluation. The Computational Thinking Test consisted of the following three dimensions:

- **Computational concepts address:** Each item addressed one or more of the following computational thinking concepts (basic directions and sequences, loops, conditionals, conditional loops, and simple functions).
- **Style of response options:** In each item, responses were depicted either by visual arrows or visual blocks.
- **Required cognitive task**: For each item to be solved, it demanded one of the following cognitive tasks: to sequence an algorithm, to complete an incomplete algorithm, or to debug an incorrect algorithm.

Based on the literature review, the components of computational thinking differ from researcher to researcher. However, the essential elements amongst researchers have been identified as decomposition, pattern recognition, abstraction, algorithmic thinking, and evaluation. The researcher used the Computational Thinking test as guidance to develop the questionnaires for this study. Referring back to the three dimensions of the Computational Thinking Test; the researcher made the following adjustments:

- **Computational concepts address:** The pre- and post-test questionnaires have been set up to address the components identified in this study which is decomposition, pattern recognition, abstraction, algorithmic thinking, and evaluation. The number of questions have also been reduced to 12 questions due to the time limit of the winter school session.
- **Style of response action:** Four possible answers were given at each question in the form of sentences; they were depicted as single-select multiple choice answers.
- **Required cognitive task**: For each question to be answered, it demanded one of the following cognitive tasks: define the component and apply it in an example.

Each of the twelve questions were in relation to one of the components of computational thinking identified in the study (see the complete questionnaire in appendix C). Table 5 depicts how the questions are mapped to the components of computational thinking identified in this study.

No.	Question	Component
Q1	What is computational thinking?	Computational Thinking
Q2	Which of the following is an example of computational thinking?	Computational Thinking
Q3	In which of the following disciplines can computational thinking be applied?	Computational Thinking
Q4	What is decomposition?	Decomposition
Q5	What is an example of decomposition?	Decomposition
Q6	What is pattern recognition?	Pattern Recognition
Q7	What is an example of pattern recognition?	Pattern Recognition
Q8	What is abstraction?	Abstraction
Q9	What is an example of abstraction?	Abstraction
Q10	What is algorithmic design?	Algorithmic Design
Q11	What is an example of algorithmic design?	Algorithmic Design
Q12	What is evaluation	Evaluation

Table 5: Mapping of how the questions relate to the components of computational thinking

Evaluation Questionnaire

The evaluation questionnaire consisted of three Likert scale questions and one open-ended question. The questions were all aimed at determining how students experienced the learning process.

3.8.4.1.6. Virtual Escape Room Design

The escape room were designed with the assistance of the VEscapeCT framework (see figure 7 in chapter 2) identified in the previous phases. The narrative revolved around a hacker who planted a virus on a computer. It consisted of 6 puzzles all related to the components of computational thinking.

Table 6 describes the puzzles that were implemented in the virtual escape room and how they map to the components of computational thinking (see appendix A for more detail on the layout of the virtual escape room).

No.	Puzzle Description	CT Component
1	Break the code to find the new password	Decomposition
2	Complete the sequence to enable the firewall	Pattern Recognition
3	Identify the additional anti-virus software programs that have been installed due to the virus by identify 5 unique symbols. Each symbol represents an anti-virus software type.	Abstraction
4	Complete the crossword to identify the anti-virus software that needs to remain on the computer.	Abstraction
5	Update the anti-virus software by completing the algorithm	Algorithmic Thinking
6	Open your incoming mail but avoid emails from unknown sources	Pattern Recognition

Table 6: Virtual Escape Room V1 Mapping

3.8.4.2. Cycle 2:

The second cycle allowed the researcher to refine the VEscapeCT framework designed in the first cycle.

3.8.4.2.1. Data Analysis

To analyse the responses of the questionnaires received in the previous cycle, the researcher used the process of thematic analysis coding to transform the answers into a set of meaningful data. A key was assigned to each answer. Descriptive statistics were then used to identify how the students performed at each question. The results showed that the puzzles didn't clearly communicate the components of computational thinking, because students struggled to answer the questions correctly (see Chapter 4 for a more detailed description of the findings).

3.8.4.2.2. Design the Framework

Upon completion of the analysis phase, the researcher revisited the first version of the VEscapeCT framework. Based on the results from the data analysis and the researcher's observations, the framework was adjusted (see Figure 18). The area's indicated in red represents the changes that have been made. The details of the changes are given in Chapter 4.

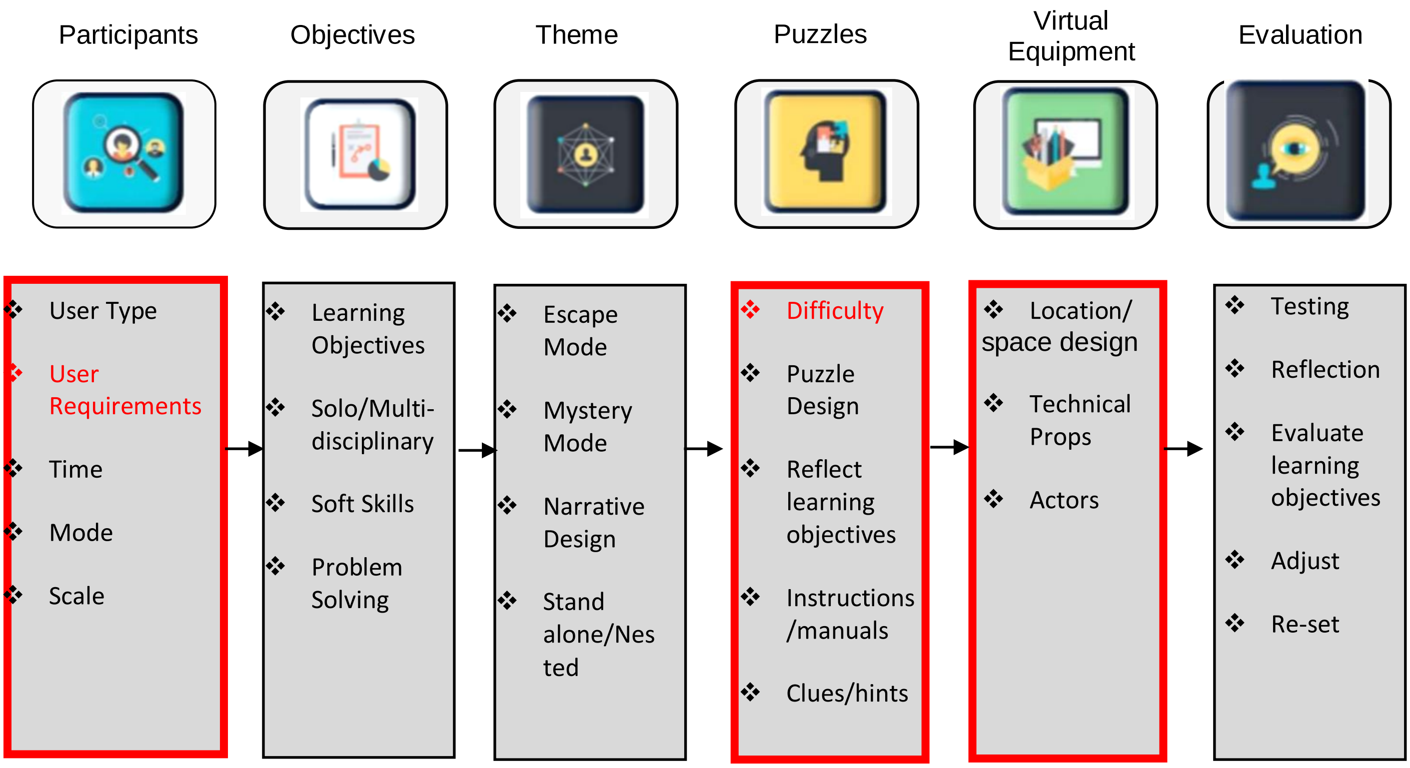


Figure 18: VEscapeCT Framework Version 2 (Adapted from Clarke et al (2017))

3.8.4.2.3. Develop the Framework

No adjustments were made to the virtual escape room or the data collection instruments at this stage of the cycle.

3.8.4.2.4. Implement the Framework

No implementation occurred at this stage of the cycle.

3.8.4.2.5. Evaluation of the Framework

During the evaluation phase, the researcher evaluated the second version of the VEscapeCT created above. The evaluation of the framework occurred in the same case study setting as cycle 1, and the type of case study utilised is exploratory. The case study setting allowed the researcher to evaluate the framework with the assistance of lecturers from the University of Pretoria, to determine how they experienced the learning process. The sampling technique that was applied by the researcher was the judgement sampling technique. The lecturers were selected based on their involvement in first-year Informatics modules such as INF 154, INF 164, and INF 113 (modules that include programming and computational thinking components), where they will be able to provide more accurate feedback that, in return, would benefit the research study. The sample size consisted of two lecturers. Interviews were selected as the primary data collection tool and thematic analysis and descriptive statistics as the data analysis techniques.

3.8.4.3. Cycle 3:

The third cycle allowed the researcher to refine the VEscapeCT framework created in the second cycle as well as the virtual escape room that was developed and implemented during the first cycle of the study.

3.8.4.3.1. Analysis

To analyse the feedback received during the interviews conducted in the previous cycle, the researcher used thematic analysis that involves looking for patterns of meaning within-the data set. According to the feedback, the lecturers also experienced that some of the puzzles didn't communicate the components of computational thinking properly (see Chapter 4 for a more detailed description of the findings).

3.8.4.3.2. Design the Framework

No adjustments were made to the framework at this stage of the cycle. The adjustments to the framework were only implemented at the end of the cycle.

3.8.4.3.3. Develop the Framework

Based on the results of the questionnaires implemented during the first cycle and the interviews conducted during the second cycle, it was clear that the researcher had to take another look at the puzzles of the virtual escape room. With the assistance of the second version VEscapeCT framework, the researcher re-designed the virtual escape room by re-iterating back to the start of the framework (see appendix B for more details on the layout of the virtual escape room). No adjustments were made to the rest of the data collection instruments.

1.8.4.3.4. Implement the Framework

The implementation phase occurred in a case study setting (case study 2). The type of case study utilized is exploratory because the researcher explored how the framework can assist students in their current programming module through teaching problem solving skills, such as computational thinking. The target population focused on first-year students from the Department of Informatics at the University of Pretoria, specifically students who took INF 164 (programming in second semester) as a module. The sampling technique that was applied by the researcher was convenience sampling because the group of students that attended the INF 164 lecture was available to participate. There were no inclusion criteria that was identified prior to the selection of the students, therefore, all the students were invited to participate. The sample size consisted of 62 students, which was not a sample size selected by the researcher, but the number of students that attended the INF 164 lecture session. A total of 182 students was enrolled for the module.

1.8.4.3.5. Evaluation of the Framework

The evaluation phase involved the evaluation of the second version VEscapeCT framework and the way it was implemented. Questionnaires were selected as the primary data collection tool, and descriptive statistics as the data analysis technique. The design of the questionnaires followed the same process as explained in the first cycle (see appendix C for more detail).

3.8.4.3.6. Virtual Escape Room Design

The escape room were designed with the assistance of the second version VEscapeCT framework created in the second cycle. The narrative revolved around a student who planted a virus on his friends' memory stick.

Table 7 describes the puzzles that were implemented in the virtual escape room and how they map to the components of computational thinking (see appendix B for more detail on the layout of the virtual escape room).

No.	Puzzle Description	CT Component
1	Break the code to find the new password	Pattern Recognition
2	Unlock the correct permissions	Abstraction
3	Run the command line to enable the firewall	Abstraction
4	Update anti-virus	Algorithmic Thinking + Decomposition
5	Provide new product code for expired anti-virus	Pattern Recognition + Decomposition
6	Remove the files copied from the friends flash	Pattern Recognition

Table 7: Virtual Escape Room V2 Mapping

3.8.4.4. Final Framework

Upon completion of the last cycle, the researcher revisited and refined the VEscapeCT framework based on the results received during the last cycle (see Chapter 4 for more detail on the final framework).

3.8.5 Ethical Considerations

The researcher applied for ethical clearance in order to be able to conduct the research with the University students (see appendix D for more detail). Apart from the ethical clearance application, the following ethical considerations were also taken into account during the course of the study:

1. **Informed consent** - Participants must agree to take part in the study, they cannot be forced to participate by the researcher. The researcher must provide the participants with sufficient information for them to make an informed decision.
2. **Privacy** - The privacy of the information supplied by the participants should be respected.
3. **Integrity** – Researchers have an obligation to conduct their research with integrity. The research should be reviewed before the researcher can make any assumptions, to ensure the integrity and the quality.
4. **Fairness** – Research committees expect research to be fair. The independence of the research must be clear, and any conflicts of interest or partiality must be explicit.
5. **Feedback** – It's important for the researcher to provide feedback to the participants after the findings. This will foresee a good relationship between the researcher and the participants which is crucial for the validity of the study

4 ANALYSIS OF RESULTS

4.1 INTRODUCTION

In the previous chapter, the researcher articulated the research methodology that was followed in conducting the current study. A Design-Based research strategy was followed using three iterative cycles, each with its own research strategy, data collection method, and statistical analysis method (see Chapter 3 for more detail).

This chapter is divided into three sections, each presenting the data analysis of the abovementioned cycles. Each analysis section will contribute to the overall question of how the suggested framework can provide a way of using virtual escape rooms to facilitate computational thinking.

4.2 SECTION 1: CYCLE 1 DATA ANALYSIS

A total of fifteen students participated during the first cycle of the study, of which only four students' data were usable (n = 4), thus resulting in a 26,66% response rate. As illustrated in Chapter 3, participants included first-year students from the University of Pretoria. The first cycle commenced during an online INF 154 winter school session; there are thus various factors that may have contributed to the low response rate of the study:

- The session was not mandatory for the students.
- The activities didn't contribute towards any marks in the module.
- There were no incentives for completing the activities.

The participants each had to complete the following activities within the first cycle: pre-test, virtual escape room, and post-test. The analysis of each of these activities is presented below:

4.2.1 Pre- and Post-Test Questionnaire Results

Both pre-and post-test questionnaires were loaded under the INF 154 module folder on the University's learning management system called ClickUp (Blackboard). Unfortunately, some students did not have access to the module when the study was conducted. As a result, the questionnaire was emailed to those students. Both questionnaires consisted of 12 multiple-choice questions, each representing one of the components of computational thinking described in Chapter 3. The findings of the questionnaires are discussed in more detail in section 4.2.1.1 below:

4.2.1.1. Data Analysis

Each question contained a set of 4 answers in which the respondent had to select either a, b, c, or d. However, this made it difficult for the researcher to analyse the data. As a result, the researcher used the process of coding to transform the answers into a set of meaningful data that can be presented on a graph and in a table. To accomplish this, the researcher assigned a key to each answer, in other words, replacing the alphabetical numbering (a, b, c, and d) with a numerical key (1, 2, 3, and 4) (see Appendix H for more detail).

The feedback obtained through each questionnaire was subjected to frequency counts; in other words, the responses for each question were added together to find the highest frequency of occurrence (i.e., the number of times a particular response occurs). The responses for each question were then categorized according to students with and without INF 113 as a module. INF 113 is one of the modules offered by the Department of Informatics for undergraduate students, which includes computational thinking as part of the module curriculum. The assumption is that students who did the module, will have a better existing knowledge of computational thinking.

The analysis between the two groups of students might not be the main focus of the study; however, it does provide the researcher with an indication of whether educators will be able to use virtual escape rooms to teach students with and without computational thinking knowledge.

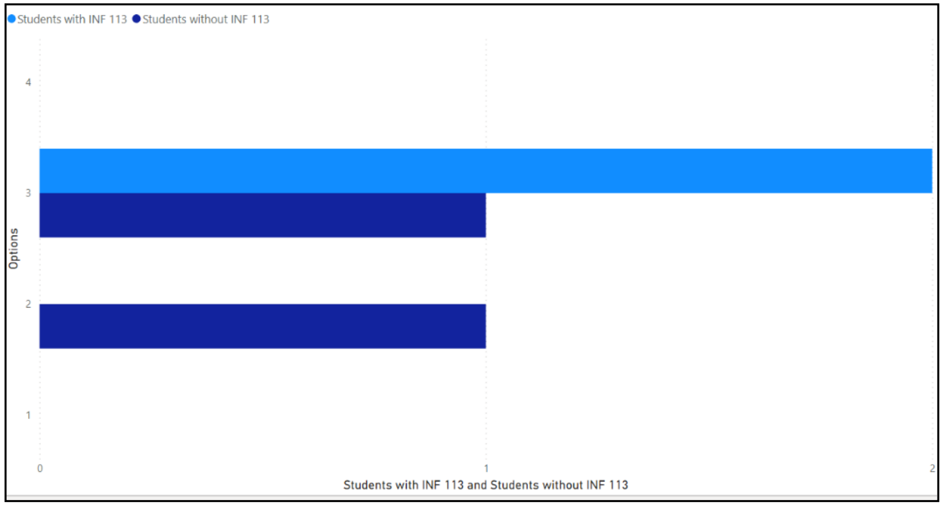
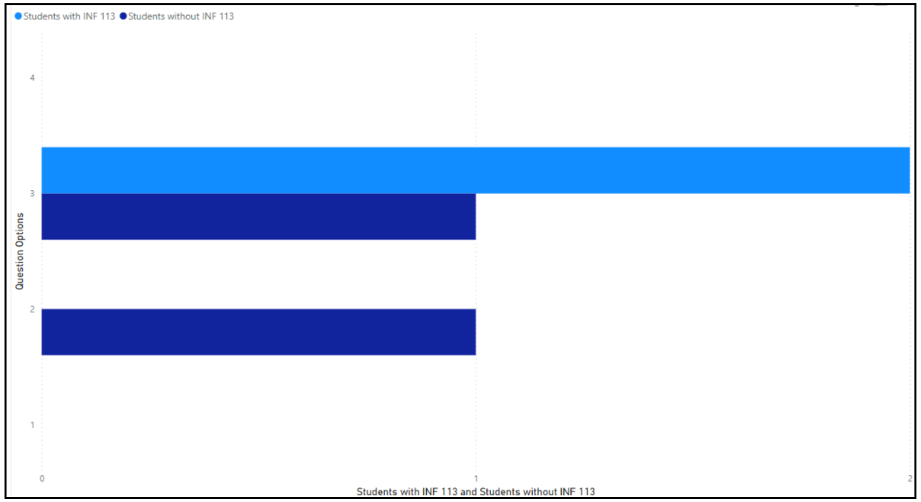
The following legends were used to identify students with and without computational thinking:

● Students with INF 113 ● Students without INF 113

The y-axis represent the answer selected by the student where the x-axis represents the total number of students.

Question 1: What is Computational Thinking?

The first question sought to identify whether respondents could demonstrate a basic understanding of computational thinking by identifying the correct definition for computational thinking.

Pre-Test	Post-Test
	

Pre-Test

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = The way computers think	-	-	
2 = A problem-solving approach that **only** computer scientists use, that involves expressing problems in a way that	1	25	

Post-Test

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = The way computers think	-	-	
2 = A problem-solving approach that **only** computer scientists use, that involves expressing problems in a way	1	25	

computers can understand			
3 = A problem-solving approach that can be used by anyone, that involves expressing problems in a way that computers can understand	3	75	☑
4 = The way computers follow instructions	-	-	

Based on the results above, 3 (75%) of the respondents identified the correct answer, while 1 (25%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	100	-
Respondents without INF 113	2	50%	50

that computers can understand			
3 = A problem-solving approach that can be used by anyone, that involves expressing problems in a way that computers can understand	3	75	☑
4 = The way computers follow instructions	-	-	

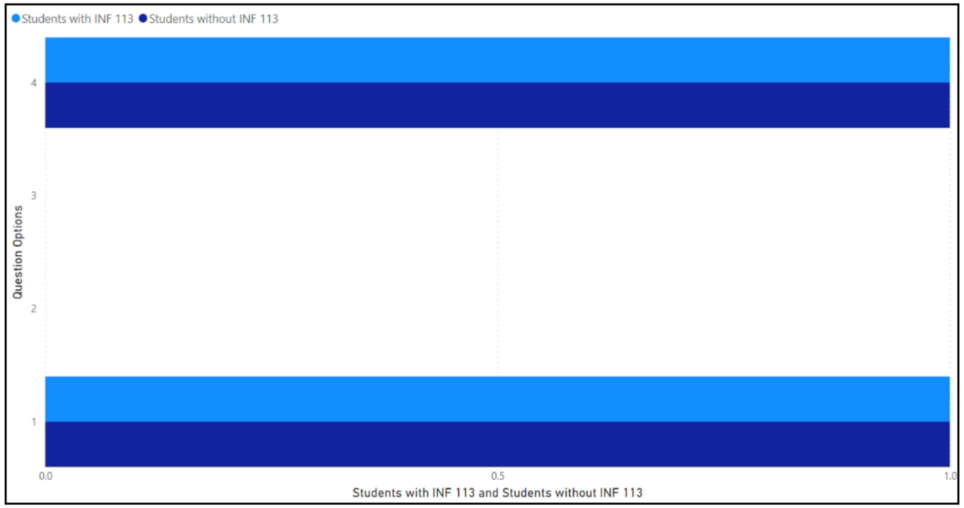
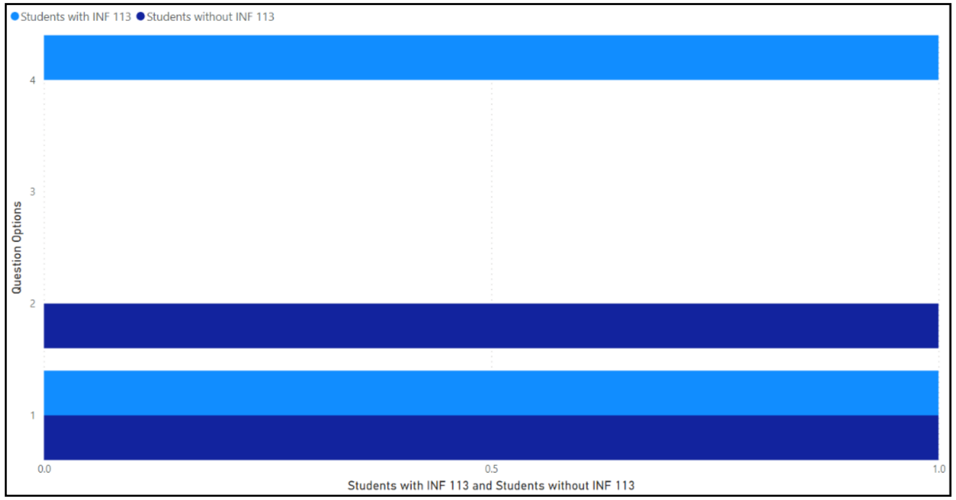
Based on the results above, 3 (75%) of the respondents identified the correct answer, while 1 (25%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	100	-
Respondents without INF 113	2	50	50

Table 8: What is Computational Thinking? (Cycle 1)

Question 2: Which of the following is an example of computational thinking?

The second question sought to identify whether respondents could apply the definition of computational thinking to identify an example in which computational thinking can be applied.

Pre-Test	Post-Test
	

Pre-Test

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Sorting of important documents	2	50	
2 = Choosing a line at the supermarket	-	-	
3 = Running Errands	-	-	

Post-Test

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Sorting of important documents	3	75	
2 = Choosing a line at the supermarket	-	-	
3 = Running Errands	-	-	

4 = All of the above	2	50	☑

Based on the results above, 2 (50%) of the respondents identified the correct answer, while 2 (50%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	50	50
Respondents without INF 113	2	50	50

4 = All of the above	1	25	☑

Based on the results above, 1 (25%) of the respondents identified the correct answer, while 3 (75%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

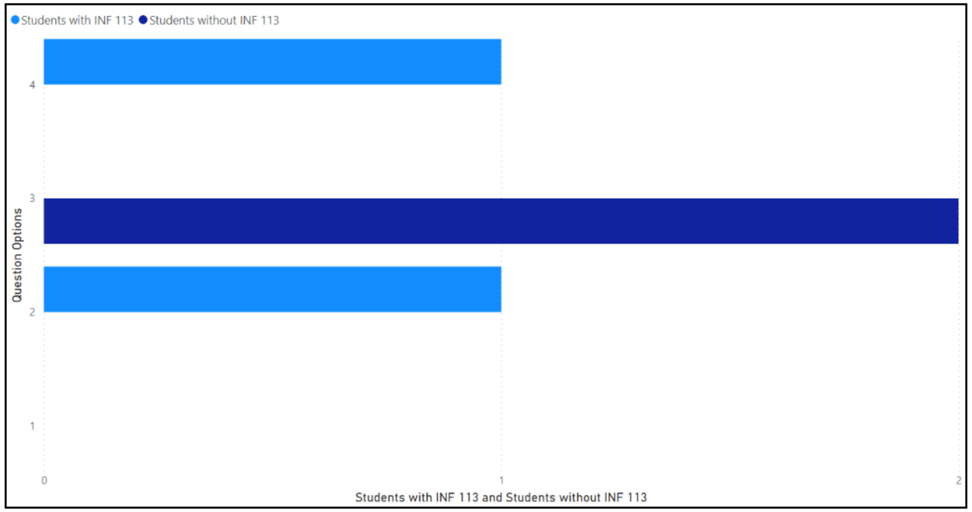
Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	50	50
Respondents without INF 113	2	-	100

Table 9: Which of the following is an example of computational thinking? (Cycle 1)

Question 3: In which of the following disciplines can computational thinking be applied?

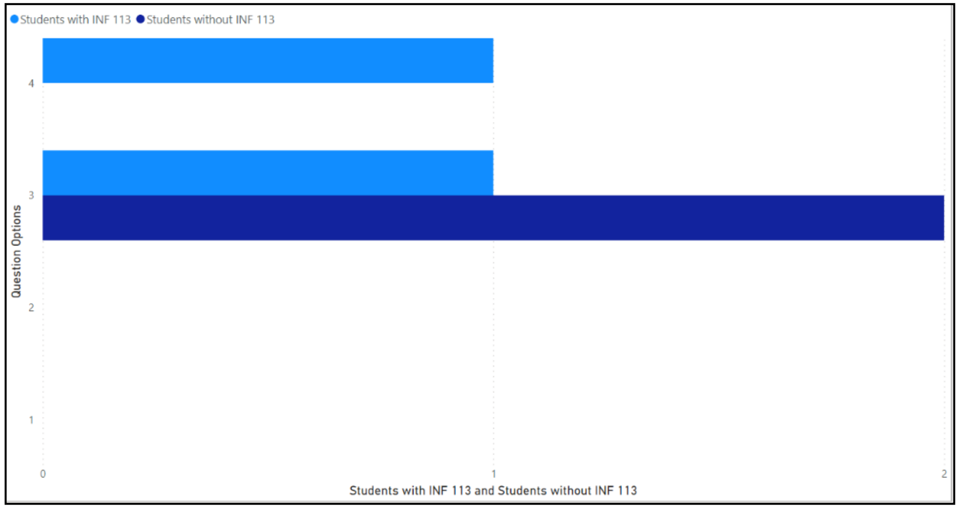
The third question sought to identify whether respondents could further apply the concept of computational thinking by identifying a discipline in which computational thinking can be used.

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = English Literature	-	-	
2 = Mathematics	1	25	
3 = Computer Science	2	50	
4 = All of the above	1	25	☑

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = English Literature	-	-	
2 = Mathematics	-	-	
3 = Computer Science	3	75	
4 = All of the above	1	25	☑

Based on the results above, 1 (25%) of the respondents identified the correct answer, while 3 (75%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	50	50
Respondents without INF 113	2	-	100

Based on the results above, 1 (25%) of the respondents identified the correct answer, while 3 (75%) of the respondents identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

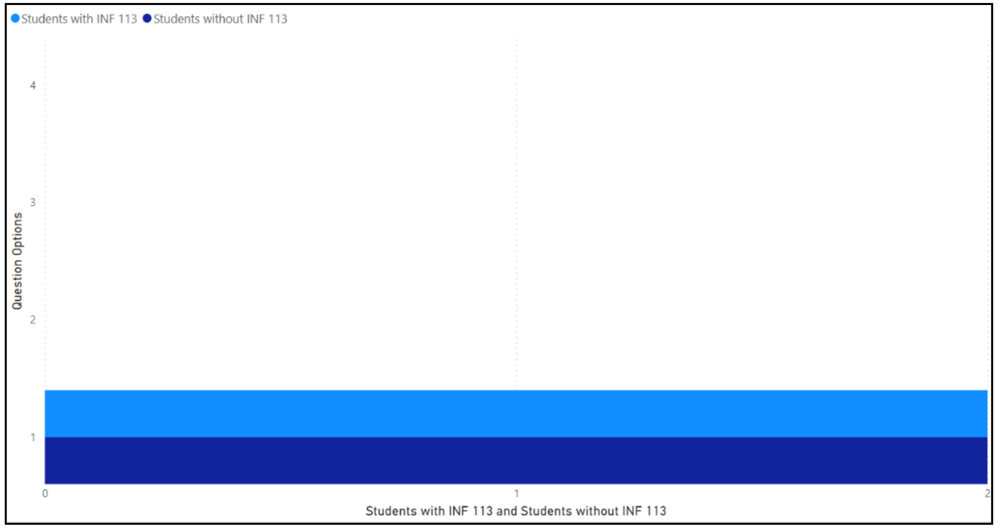
Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	50	50
Respondents without INF 113	2	-	100

Table 10: In which of the following disciplines can computational thinking be applied? (Cycle 1)

Question 4: What is decomposition?

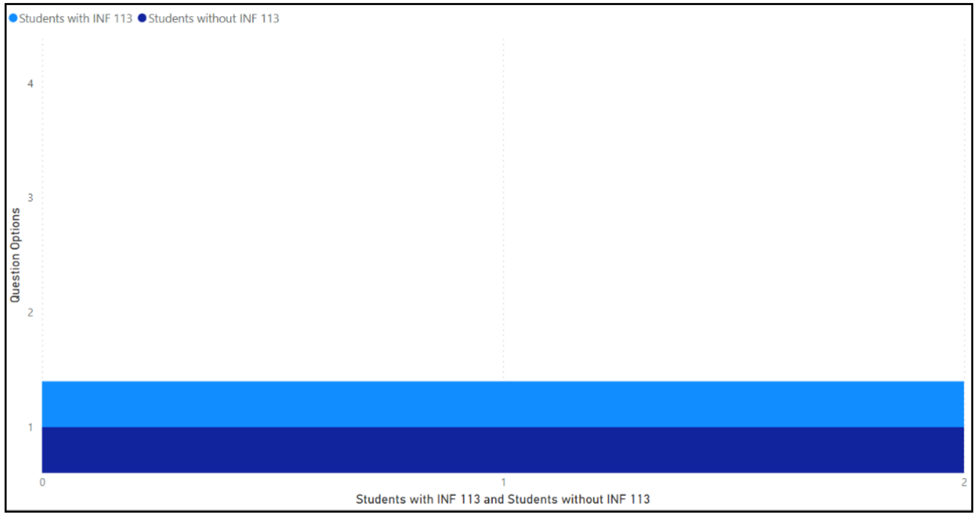
The fourth question sought to identify whether respondents could demonstrate a basic understanding of decomposition by identifying the correct definition for decomposition.

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Breaking a big problem into smaller problems that are easier to solve	4	100	☑

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Breaking a big problem into smaller problems that are easier to solve	4	100	☑

2 = Removing necessary details in a problem	-	-	
3 = Breaking a big problem into smaller problems that challenges our way of thinking	-	-	
4 = Removing unnecessary details in a problem	-	-	

Based on the results above, all four respondents identified the correct answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	100	-
Respondents without INF 113	2	100	-

2 = Removing necessary details in a problem	-	-	
3 = Breaking a big problem into smaller problems that challenges our way of thinking	-	-	
4 = Removing unnecessary details in a problem	-	-	

Based on the results above, all four respondents identified the correct answer. The results between the respondents with and without INF 113 were as follow:

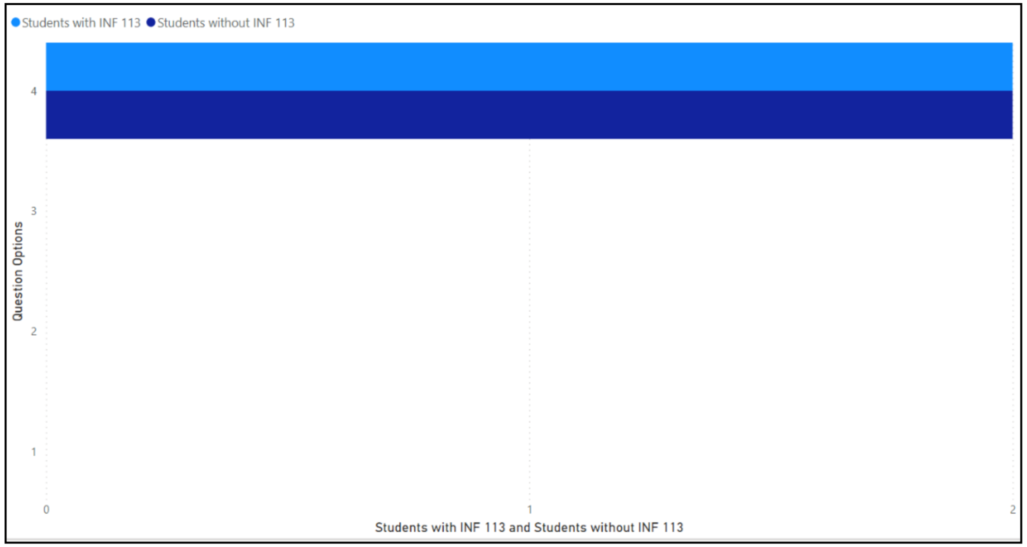
Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	100	-
Respondents without INF 113	2	100	-

Table 11: What is decomposition? (Cycle 1)

Question 5: What is an example of decomposition?

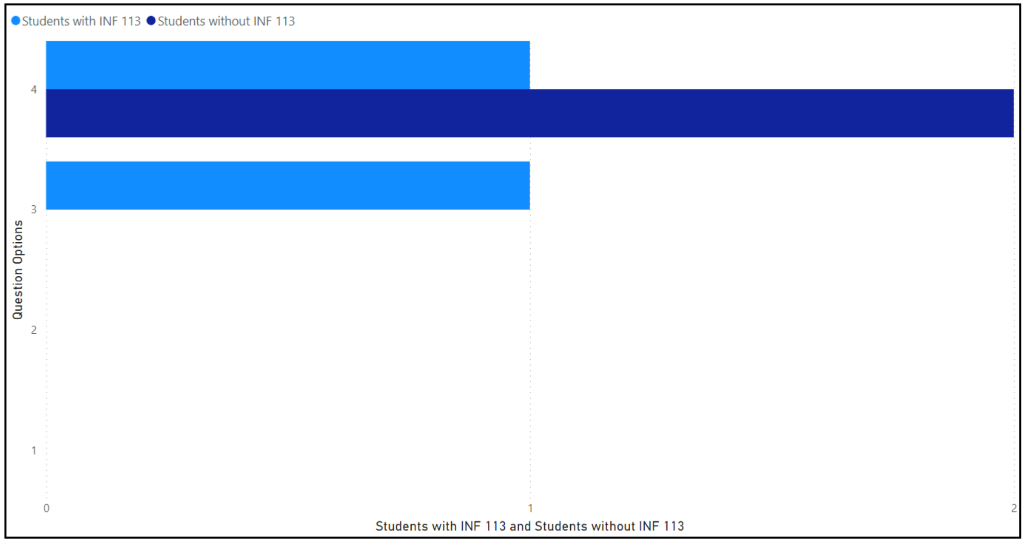
The fifth question sought to identify whether respondents could apply the definition of decomposition by identifying the correct example in which decomposition can be used.

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Baking a cake	-	-	
2 = Looking at what different kind of cakes can be made	-	-	
3 = Thinking about how we can make it the best	-	-	

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Baking a cake	-	-	
2 = Looking at what different kind of cakes can be made	-	-	
3 = Thinking about how we can make it the best	1	25	

cake			
4 = When baking a cake, thinking about what ingredients to get together, what the method is and how the cake should be decorate	4	100	☑

Based on the results above, all four respondents identified the correct answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	100	-
Respondents without INF 113	2	100	-

cake			
4 = When baking a cake, thinking about what ingredients to get together, what the method is and how the cake should be decorate	3	75	☑

Based on the results above, 3 (75%) of the respondents identified the correct answer, while 1 (25%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

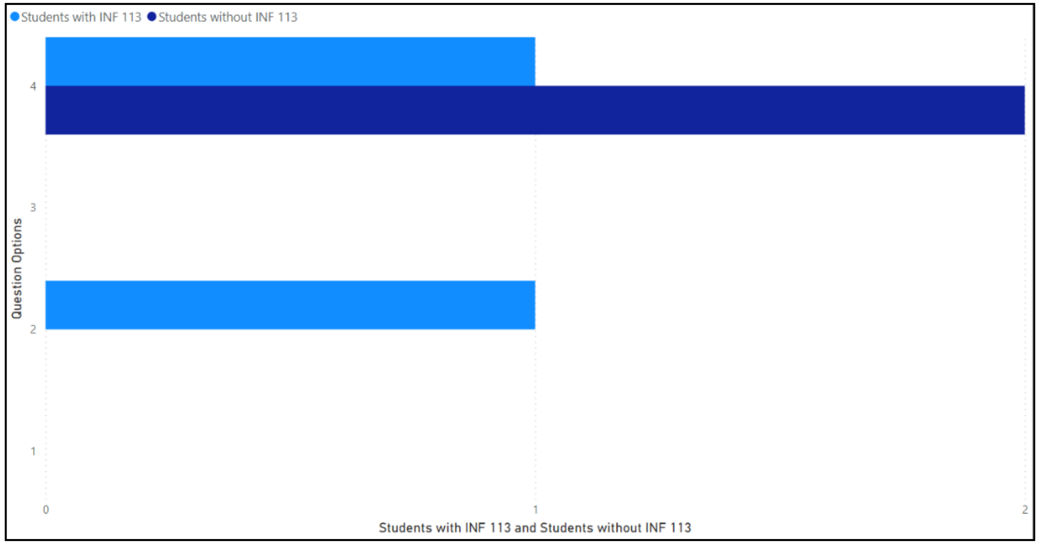
Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	50	50
Respondents without INF 113	2	100	-

Table 12: What is an example of decomposition? (Cycle 1)

Question 6: What is pattern recognition?

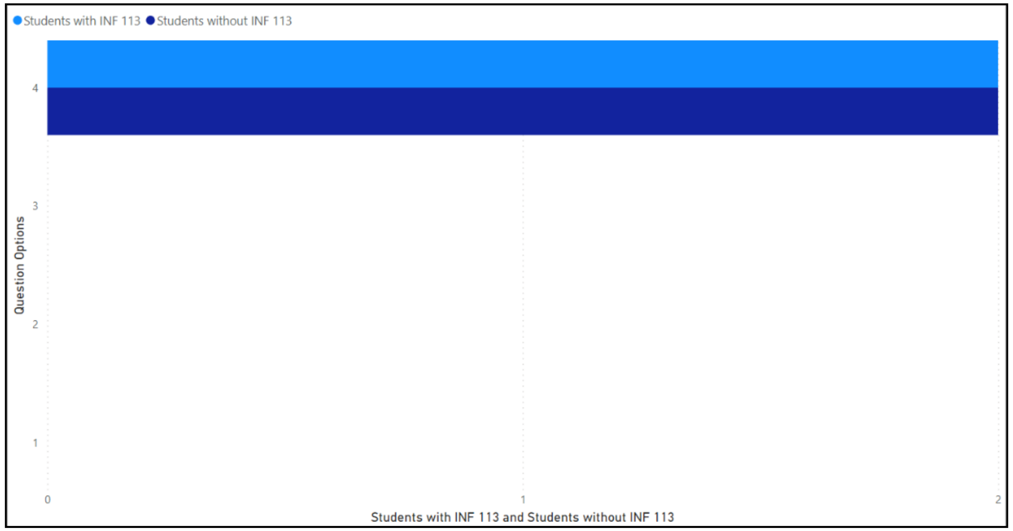
The sixth question sought to identify whether respondents could demonstrate a basic understanding of pattern recognition by identifying the correct definition for pattern recognition.

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Removing unnecessary details from a problem	-	-	
2 = Identifying differences in problems	1	25	

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Removing unnecessary details from a problem	-	-	
2 = Identifying differences in problems	-	-	

3 = Removing unnecessary details from a problem	-	-	
4 = Identifying similarities in problems	3	75	☑

Based on the results above, 3 (75%) of the respondents identified the correct answer, while 1 (25%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	50	50
Respondents without INF 113	2	100	-

3 = Removing unnecessary details from a problem	-	-	
4 = Identifying similarities in problems	4	100	☑

Based on the results above, all four respondents identified the correct answer. The results between the respondents with and without INF 113 were as follow:

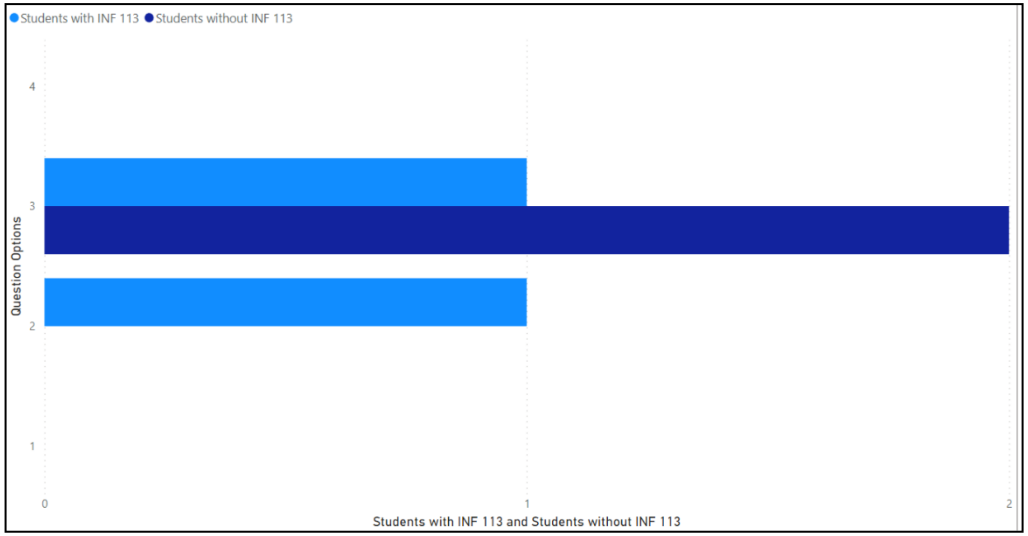
Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	100	-
Respondents without INF 113	2	100	-

Table 13: What is pattern recognition? (Cycle 1)

Question 7: What is an example of pattern recognition?

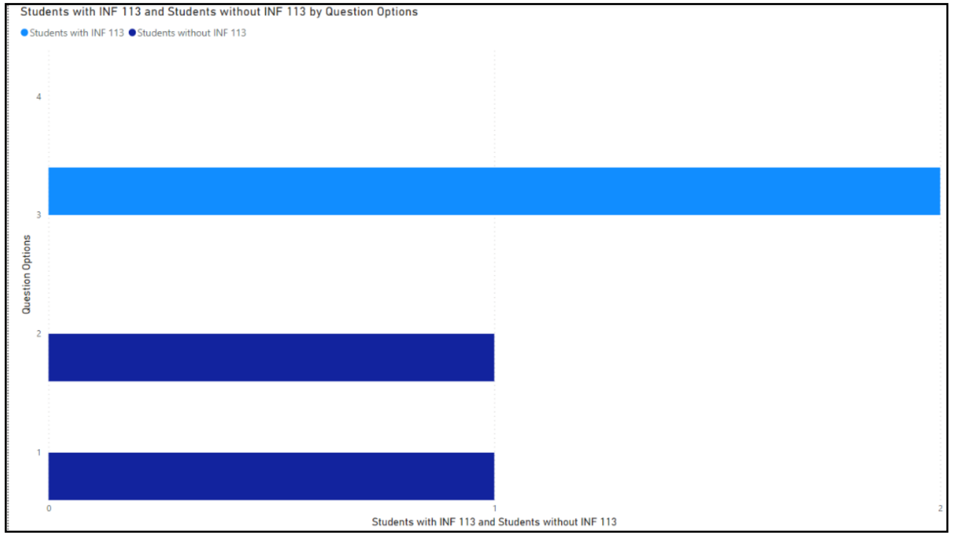
The seventh question sought to identify whether respondents could apply the definition of pattern recognition by identifying the correct example in which pattern recognition can be used.

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Uploading a photo to Facebook	-	-	
2 = Facebook's Location Services	1	25	
3 = Facebook's Facial Recognition	3	75	☑
4 = Uploading a photo to Instagram	-	-	

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Uploading a photo to Facebook	1	25	
2 = Facebook's Location Services	1	25	
3 = Facebook's Facial Recognition	2	50	☑
4 = Uploading a photo to Instagram	-	-	

Based on the results above, 3 (75%) of the respondents identified the correct answer, while 1 (25%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	50	50
Respondents without INF 113	2	100	-

Based on the results above, 2 (50%) of the respondents identified the correct answer, while 2 (50%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	100	-
Respondents without INF 113	2	-	100

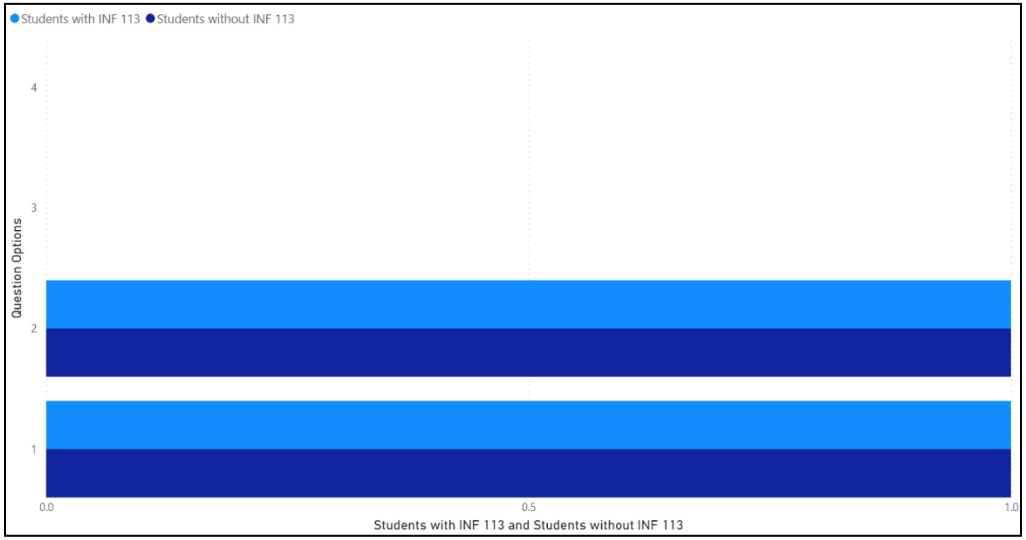
Table 14: What is an example of pattern recognition? (Cycle 1)

Question 8: What is abstraction?

The eighth question sought to identify whether respondents could demonstrate a basic understanding of abstraction by identifying the correct definition for abstraction.

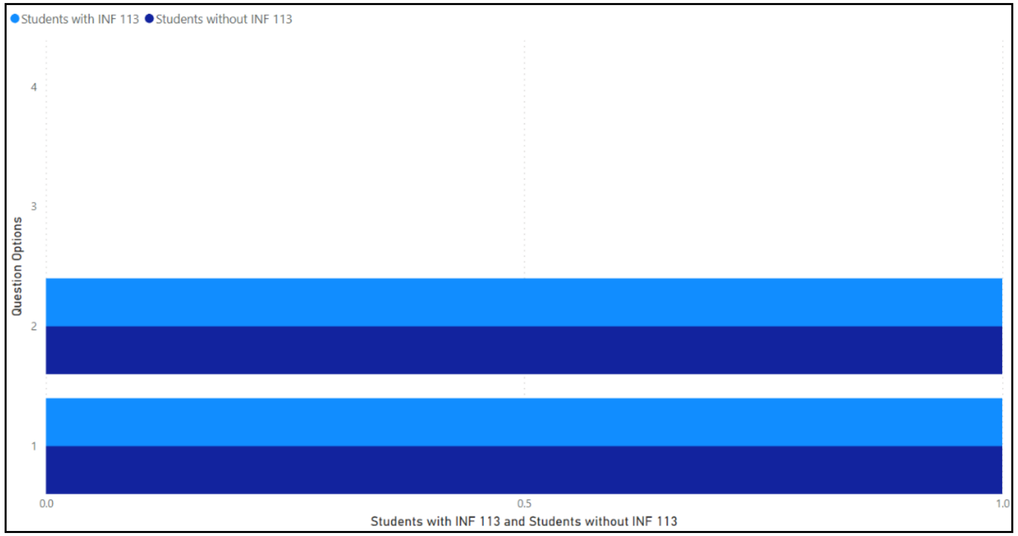
Pre-Test	Post-Test

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Drawing conclusions from problems by applying abstract thinking	2	50	
2 = Simplifying a problem by only dealing with the important details and neglecting the unnecessary	2	50	☑

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Drawing conclusions from problems by applying abstract thinking	2	50	
2 = Simplifying a problem by only dealing with the important details and neglecting the unnecessary	2	50	☑

details			
3 = Simplifying a problem by only dealing with the unimportant details and neglecting the necessary details	-	-	
4 = Drawing important details from problems by applying abstract thinking	-	-	

Based on the results above, 2 (50%) of the respondents identified the correct answer, while 2 (50%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	50	50
Respondents without INF 113	2	50	50

details			
3 = Simplifying a problem by only dealing with the unimportant details and neglecting the necessary details	-	-	
4 = Drawing important details from problems by applying abstract thinking	-	-	

Based on the results above, 2 (50%) of the respondents identified the correct answer, while 2 (50%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

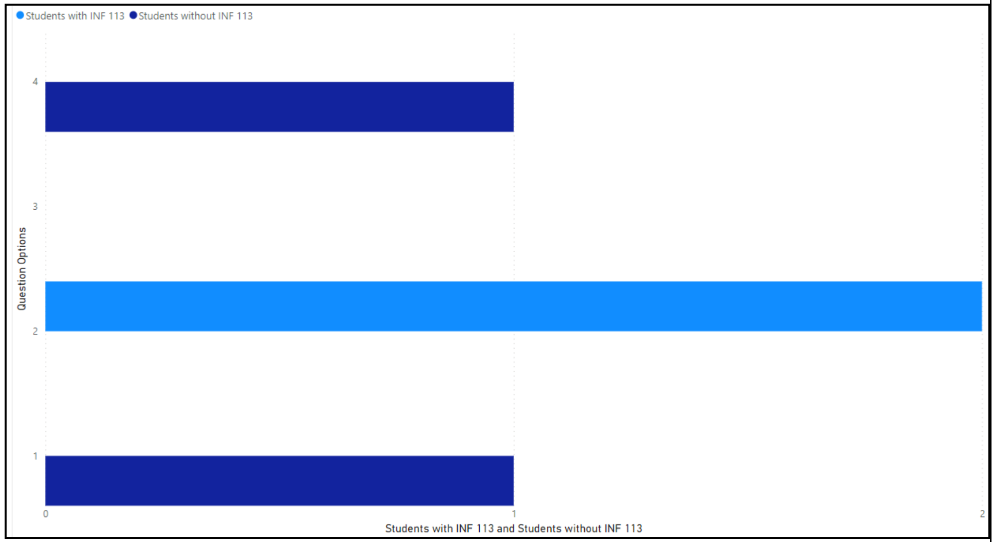
Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	100	-
Respondents without INF 113	2	-	100

Table 15: What is abstraction? (Cycle 1)

Question 9: What is an example of abstraction?

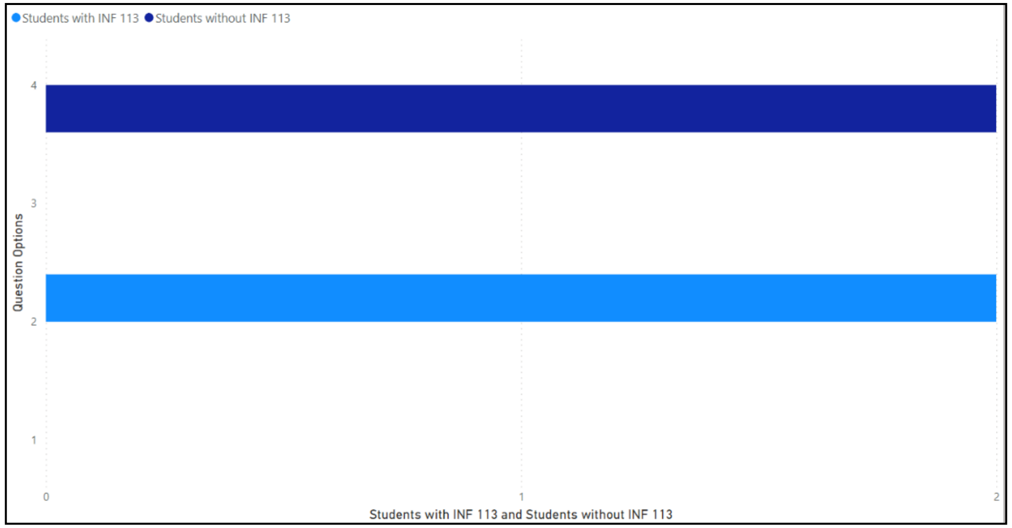
The ninth question sought to identify whether respondents could apply the definition of abstraction by identifying an example in which abstraction can be used.

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = A Map	1	25	
2 = A house plan	2	50	
3 = A sign of an isle store	-	-	

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = A Map	1	25	
2 = A house plan	2	50	
3 = A sign of an isle store	-	-	

4 = All of the above	1	25	☑

Based on the results above, 1 (25%) of the respondents identified the correct answer, while 3 (75%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	-	100
Respondents without INF 113	2	50	50

4 = All of the above	2	50	☑

Based on the results above, 2 (50%) of the respondents identified the correct answer, while 2 (50%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

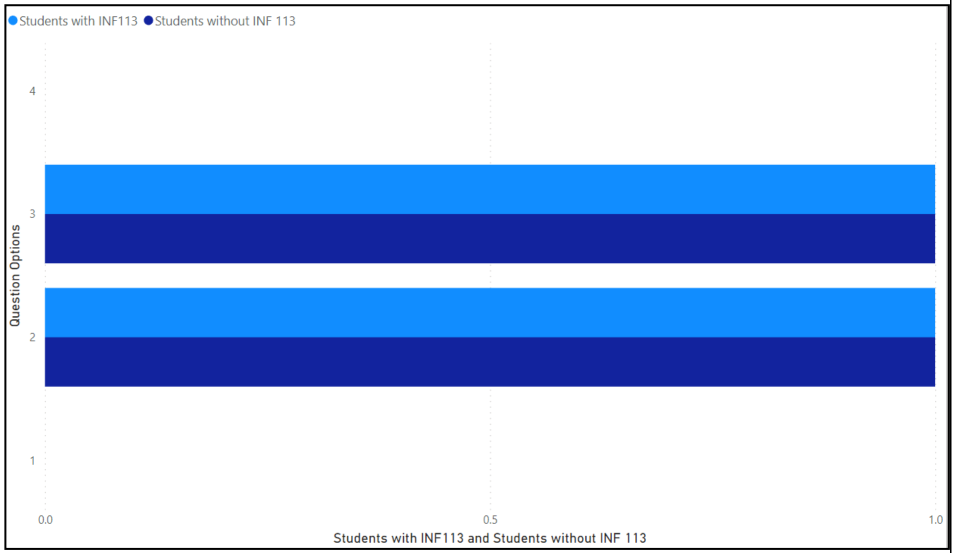
Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	-	100
Respondents without INF 113	2	100	-

Table 16: What is an example of abstraction? (Cycle 1)

Question 10: What is algorithmic thinking?

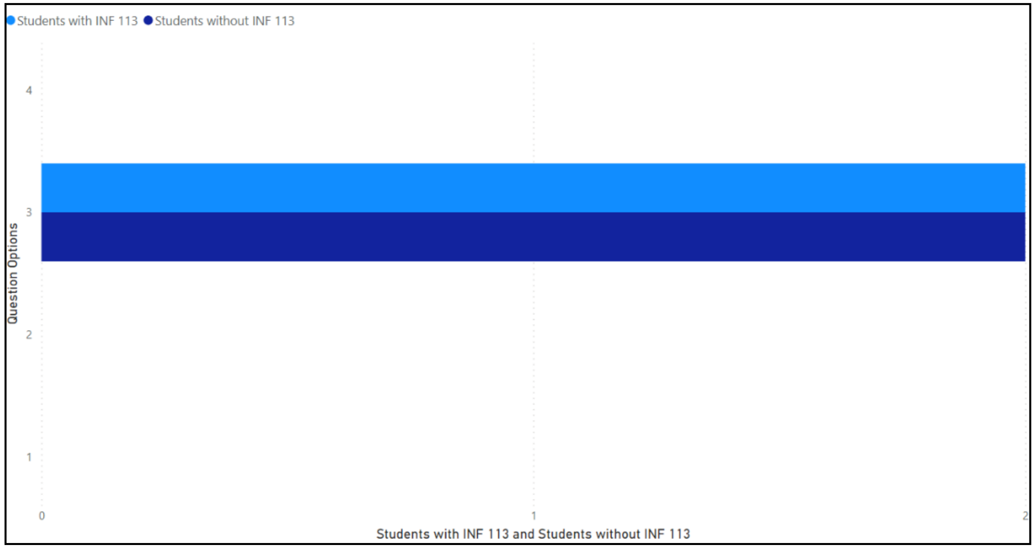
The tenth question sought to identify whether respondents could demonstrate a basic understanding of algorithmic thinking by identifying the correct definition for algorithmic thinking.

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Developing the necessary input to solve a problem	-	-	
2 = Developing the necessary processing to	2	50	

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Developing the necessary input to solve a problem	-	-	
2 = Developing the necessary processing to solve a	-	-	

solve a problem			
3 = Developing the necessary step-by step solution to solve a problem	2	50	☑
4 = Developing the necessary output to solve a problem	-	-	

Based on the results above, 2 (50%) of the respondents identified the correct answer, while 2 (50%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	50	50
Respondents without INF 113	2	50	50

problem			
3 = Developing the necessary step-by step solution to solve a problem	4	100	☑
4 = Developing the necessary output to solve a problem	-	-	

Based on the results above, all four respondents identified the correct answer. The results between the respondents with and without INF 113 were as follow:

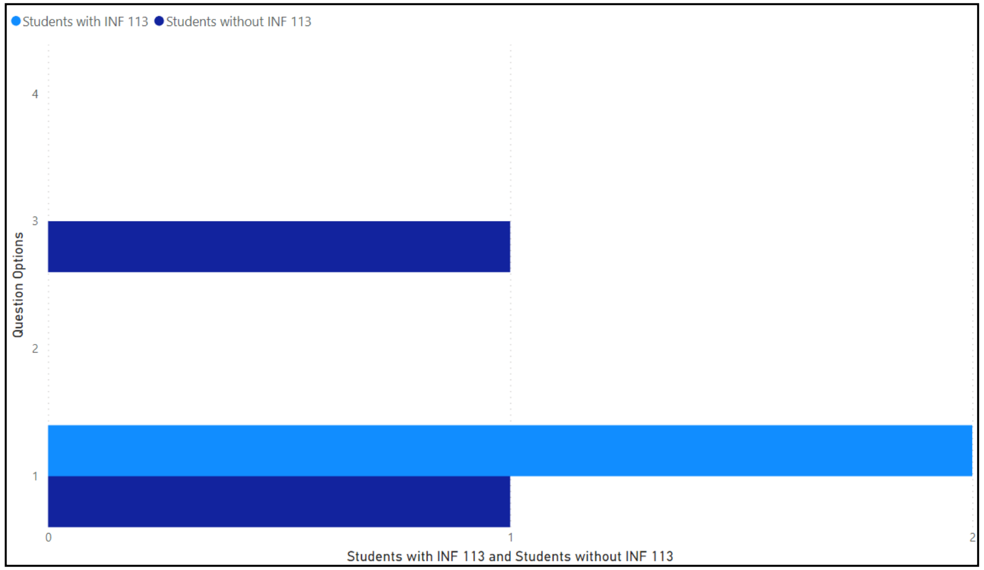
Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	100	-
Respondents without INF 113	2	100	-

Table 17: What is algorithmic thinking? (Cycle 1)

Question 11: What is an example of algorithmic thinking?

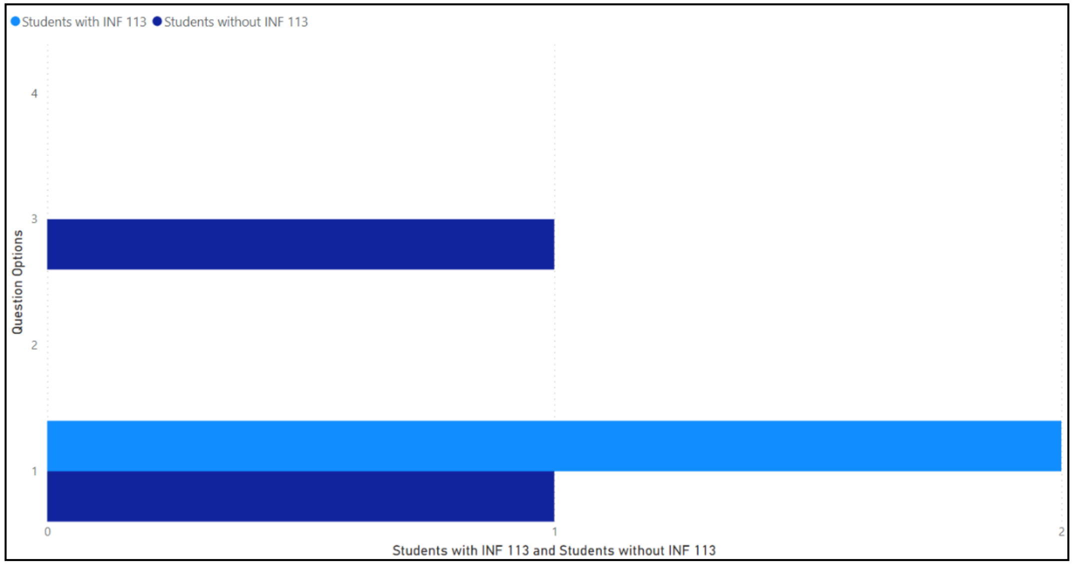
The eleventh question sought to identify whether respondents could apply the definition of algorithmic thinking by identifying the correct example in which algorithmic thinking can be applied

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = An installation manual	3	75	☑
2 = A comic strip	-	-	
3 = A map	1	25	
4 = A list of items on sale	-	-	

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = An installation manual	3	75	☑
2 = A comic strip	-	-	
3 = A map	1	25	
4 = A list of items on sale	-	-	

Based on the results above, 3 (75%) of the respondents identified the correct answer, while 1 (25%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	2	0
Respondents without INF 113	2	1	1

Based on the results above, 3 (75%) of the respondents identified the correct answer, while 1 (25%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

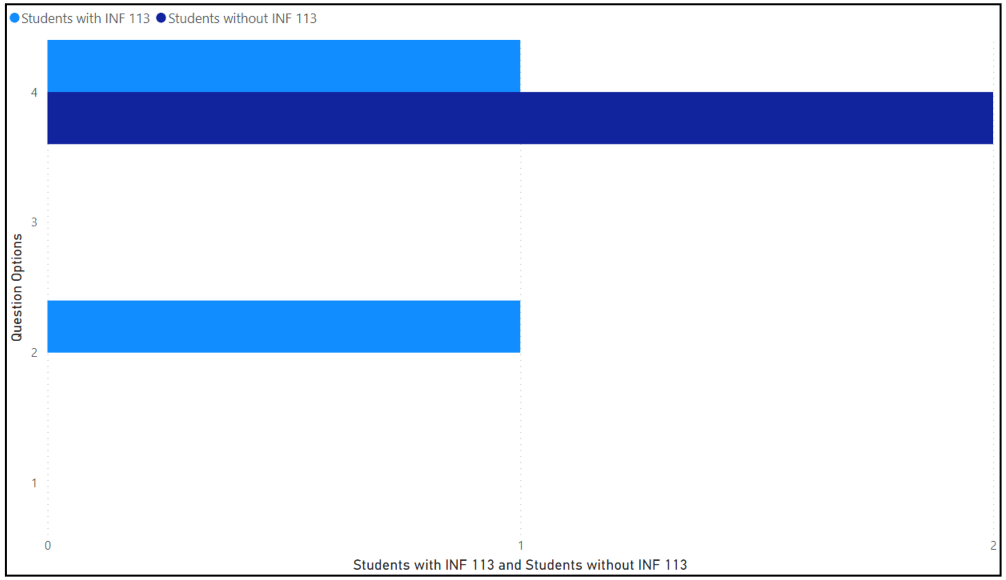
Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	2	0
Respondents without INF 113	2	1	1

Table 18: What is an example of algorithmic thinking? (Cycle 1)

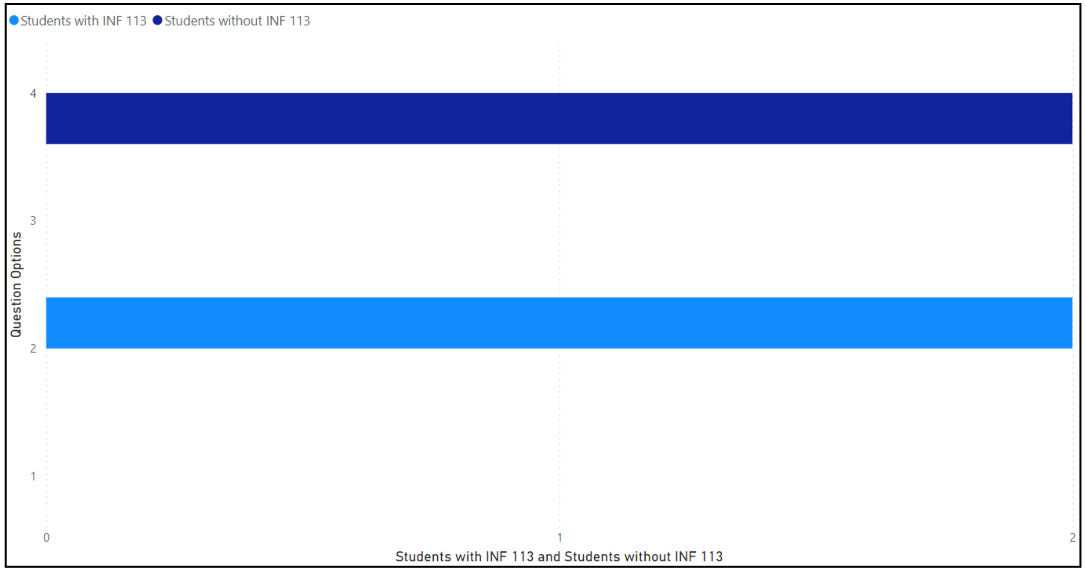
Question 1.12: What is evaluation?

The eleventh question sought to identify whether respondents could apply the definition of algorithmic thinking by identifying the correct example in which algorithmic thinking can be used.

Pre-Test



Post-Test



Pre-Test

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Evaluating solutions for any similarities	-	-	
2 = Evaluating solutions against desired outcomes	1	25	

Post-Test

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Evaluating solutions for any similarities	-	-	
2 = Evaluating solutions against desired outcomes	2	50	

3 = Evaluating certain parts of the solution	-	-	
4 = All of the above	3	75	☑

Based on the results above, 3 (75%) of the respondents identified the correct answer, while 1 (25%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	50	50
Respondents without INF 113	2	100	-

3 = Evaluating certain parts of the solution	-	-	
4 = All of the above	2	50	☑

Based on the results above, 2 (50%) of the respondents identified the correct answer, while 2 (50%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	2	-	100
Respondents without INF 113	2	100	-

Table 19: What is evaluation? (Cycle 1)

4.2.2 Pre- and Post-Test Analysis

Due to the number of respondents that participated in the first round of the study, the researcher could not conduct a t-test. As a result, the researcher calculated an average for each group since both groups contained the same number of students (see Table 14 for more details).

		Average (%)	
Group	**Number of Students**	**Pre-Test**	**Post-Test**
Respondents with INF 113	2	63	71
Respondents without INF 113	2	67	63

Table 20: Pre-and Post-Test Analysis (Cycle 1)

The pre-test analysis shows that the group of students without INF 113 achieved a higher average; however, this does not indicate any significance because they might have guessed the answers due to their lack of knowledge. By looking at the post-test analysis, it is clear that the group of students with INF 113 achieved a higher average while also improving by 8% compared to the pre-test. The researcher found it difficult to determine whether the virtual escape room significantly impacted the post-test results due to the number of students that participated.

The virtual escape room that the groups of students completed between the pre- and post-test will be discussed in more detail in the next section.

4.2.3 Virtual Escape Room and Framework

This section will be divided into two sub-sections: (1) the framework that guided the creation of the virtual escape room, and (2) the virtual escape room that resulted from the framework.

4.2.3.1. VEscapeCT Version 1

The framework that guided the virtual escape room, which also was the first version of the VEscapeCT framework of the study, was the framework developed by Clarke et al., (2017): It consists of six main areas: participants, objectives, theme, puzzle, equipment and evaluation. Each of these elements will be explained in more detail below:

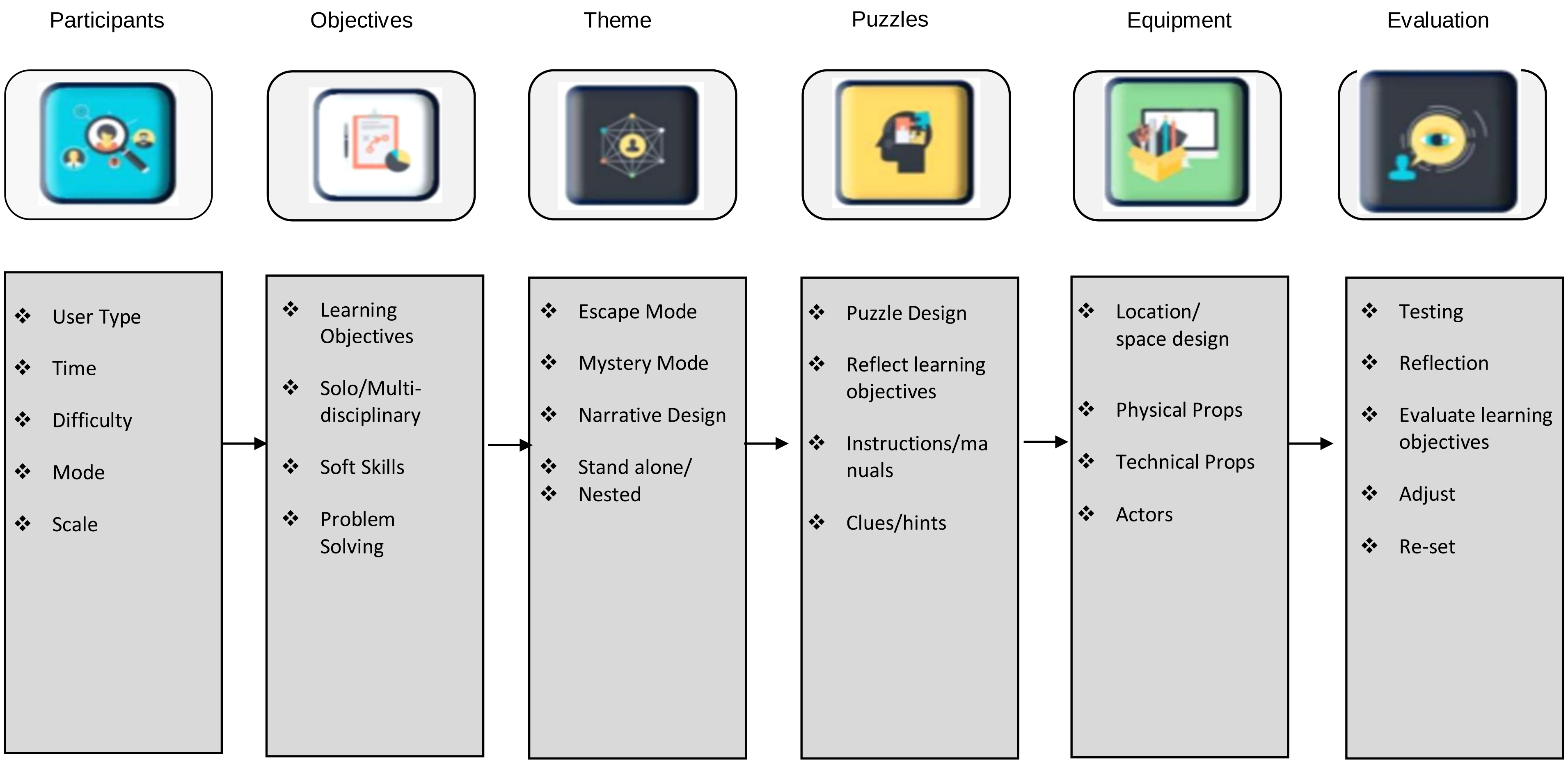


Figure 19: VEscapeCT Framework Version 1 adapted from (Clarke et al., 2017)

Component	Description	Component Elements	
		Element	**How it was incorporated?**
Participants	The first component of the framework involves an audience analysis to understand the needs of the learners, an appropriate length of game time, the difficulty level necessary to challenge and teach, the mode, defining how players will engage with the game, and the number of players in the game.	User Type	The researcher designed the virtual escape room to assist first-year undergraduate students in learning computational thinking skills. Students did require any prior knowledge to participate since the virtual escape room was designed for a typical student with little to no understanding of computational thinking.
		Time	The researcher allocated a time of 35 minutes to complete the virtual escape room because there was only an hour and a half set out to complete the entire first cycle with the students. The researcher managed the time and provided continuous feedback on the amount of time left until the time expired.
		Difficulty	It was difficult for the researcher to determine the difficulty level at the start of the game since the puzzles each contained different difficulty levels.
		Mode	The researcher designed the virtual escape room as an individual activity but gave the students the option to work together as a team. It was not crucial for the researcher whether students completed the activity as an individual or group as it was not the game's primary purpose. The only objective for the researcher is whether the virtual escape room would manage as a stand-alone component to teach computational thinking.
		Scale	The researcher did not design the virtual escape room for a specific number of students, the activity can either be presented as an individual or a group activity.
Learning Objectives	The second step of the framework considers the desired outcomes, the scope of the content disciplines, and the development of soft skills or problem solving skills.	Learning Objectives	As stated earlier, the primary purpose of the virtual escape room is to teach students computational thinking skills. For the researcher to accomplish this objective, more focused learning outcomes had to be defined. The researcher identified the following six learning outcomes necessary to provide students with a basic level of computational thinking knowledge after completing the virtual escape room:

			1. Students will be able to demonstrate a basic understanding of computational thinking by identifying the correct definition for computational thinking and applying that knowledge in an example; 2. Students will be able to demonstrate a basic understanding of decomposition by identifying the correct definition for decomposition and applying that knowledge in an example; 3. Students will be able to demonstrate a basic understanding of pattern recognition by identifying the correct definition for pattern recognition and applying that knowledge in an example; 4. Students will be able to demonstrate a basic understanding of abstraction by identifying the correct definition for abstraction and applying that knowledge in an example; 5. Students will be able to demonstrate a basic understanding of algorithmic thinking by identifying the correct definition for algorithmic thinking and applying that knowledge in an example; 6. Students will be able to demonstrate a basic understanding of evaluation by identifying the correct definition for evaluation. 7. Students will be able to integrate the components of computational thinking when solving problems.
		Solo/Multi-Disciplinary	The researcher designed the virtual escape room as a solo disciplinary activity that involved computers and computer viruses. The researcher chose the specific topic because it fell within an IT discipline same as the module for which the INF 154 winter school was presented.
		Soft skills and problem solving	As stated earlier, the purpose of the virtual escape room is to teach computational thinking skills. The puzzles, therefore, have been designed to incorporate a variety of problem-solving challenges that target different students, for example, students who enjoy pattern puzzles, students who enjoy crosswords puzzles, students who enjoy visual puzzles, etc.

Theme	The theme component uses the defined objectives to determine if the game is an escape or resolution of a mystery, to define a narrative to advance the game, and to determine if the game is played as a standalone game or if it is part of series of games.	Escape Mode	There was no physical escape mode linked to the virtual escape room where students were locked in a room. The escape mode within the context of the virtual escape room was defined as students who had to prevent a computer virus from infecting a school's computer.
		Mystery Mode	There was no mystery mode in the virtual escape room so this section did not apply.
		Narrative Design	The narrative was designed with a general theme that most students have come across in real life. The researcher selected the theme since the participants involved students from different backgrounds, cultures, and religions, which must be considered.
		Stand-Alone/Nested	The researcher designed the virtual escape room as a stand-alone component and not as a component part of a bigger game.
Puzzle	The fourth step of the framework considers the challenge, action, reward puzzle framework, the overall puzzle path, the alignment of the learning objectives to the theme and desired outcomes, the delivery of hints, and the definition of clear game rules.	Puzzle Design	The researcher designed the puzzles to include various riddles and different types of puzzles that can appeal to diverse learners. The puzzles were organized using a sequential structure, which meant that the puzzles followed each other, so for a student to access the next puzzle, the previous puzzle has to be solved first.
		Reflect Learning Objectives	The researcher designed each puzzle to reflect on one of the components of computational thinking, which is incorporated into the learning objectives defined at the start of the game.

<table>
<tr><td></td><td></td><td>Instructions/Manuals and Clues/ Hints</td><td>Every puzzle included detailed instructions on how to complete the puzzle; however, students were allowed to ask questions at any stage if they were unsure of anything. The puzzles also included various hints that guided the students on the correct path.</td></tr>
<tr><td>Equipment</td><td>The fifth step of the framework focusses on the design and space of the location, the props required for the game, both physical and technical, and the determination if actors as non-playing characters is necessary.</td><td>Location/Space</td><td>The escape room was executed in a virtual environment, which meant that no physical location was involved.</td></tr>
<tr><td></td><td></td><td>Physical Props</td><td>There were not any physical props involved therefore this section did not apply.</td></tr>
<tr><td></td><td></td><td>Technical Props</td><td>The only technical props involved in the virtual escape room were the students' own computers that they used to participate.</td></tr>
<tr><td></td><td></td><td>Actors</td><td>There were not any actors involved therefore this section did not apply.</td></tr>
<tr><td>Evaluation</td><td>The sixth and final step of the puzzle includes prototype testing prior to the implementation of the games, post-game debrief design, and documentation of requirements to reset the game for each group of</td><td>Testing</td><td>The researcher used the following checklist to determine whether the virtual escape room was ready for the students:
<table>
<tr><th>Component</th><th>Ready/Not Ready</th></tr>
<tr><td colspan="2">Language</td></tr>
<tr><td>No spelling mistakes</td><td>□</td></tr>
</table>
</td></tr>
</table>

	participants.		Instructions are understandable	□
			Hints are understandable	□
			Puzzle scenarios are understandable	□
			Puzzles	
			Puzzle 1	
			Students can easily identify the correct code without any issues	□
			Students can continue to the next puzzle once the correct code has been entered	□
			Students receive the necessary feedback if the incorrect code is provided	□
			Puzzle 2	
			Students can easily identify the overall pattern of the diagram	□
			Students can continue to the next puzzle once the correct pattern has been entered	□
			Students receive the necessary feedback if the incorrect pattern is provided	□
			Puzzle 3	
			Students can easily identify the five unique symbols	□
			Students can continue to the next puzzle once the five unique symbols has been entered	□
			Students receive the necessary feedback if the incorrect symbols are provided	□
			Puzzle 4	
			Students can easily solve the crossword puzzle and identify the overall anti-virus software icon based on the answers	□
			Students can continue to the next puzzle once the correct anti-virus software icon has been entered	□
			Students receive the necessary feedback if the wrong anti-virus software icon has been provided	□
			Puzzle 5	
			Students can easily follow the	□

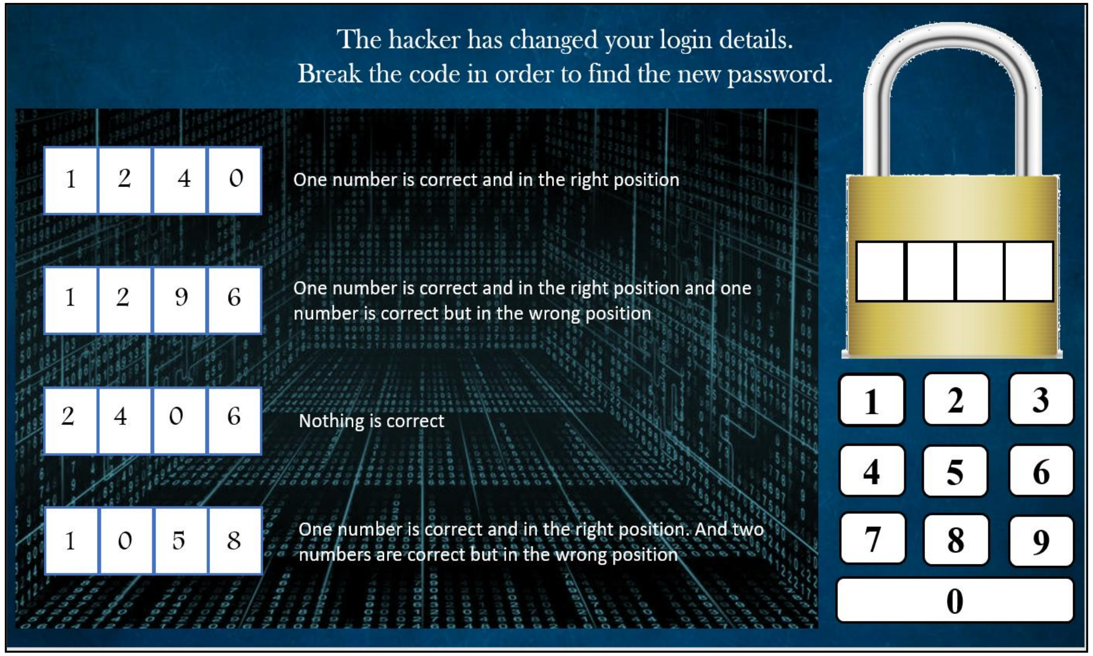
			algorithm to identify what the package details are necessary to update the anti-virus software	
			Students can continue to the next puzzle once the correct package details has been entered	□
			Students receive the necessary feedback if the wrong package details has been provided	□
			Puzzle 6	
			Students can easily spot the pattern of the flashing lights	□
			Students can finish the activity once the correct pattern has been entered	□
			Students receive the necessary feedback if the wrong pattern has been provided	□
			Interaction	
			Students are able to interact with the virtual escape room	□
			All the components that should be clickable is clickable	□
		Reflection	At the end of the virtual escape room activity, students were given an evaluation form on which they had to indicate how they experienced the virtual escape room activity. The researcher used the evaluation form to reflect on the experience.	
		Evaluate Learning Experience	The pre-and post-tests were used to indicate whether students achieved the learning outcomes as set out in the virtual escape room. The researcher compared the pre-and post-test results to determine whether there was an improvement or not and whether the learning outcomes was met.	
		Adjust	The evaluation forms provided by the students were used with other resources to adjust the virtual escape room later on in the chapter.	

		Re-Set	The researcher did not have to re-set the virtual escape room therefore this section does not apply

Table 21: VEscapeCT Framework Version 1 Components

4.2.3.2. Virtual Escape Room

By using the framework described above as guidance, the following virtual escape room was created for the students to complete:

No.	Puzzle	Description	Component of Computational Thinking
1	 **Figure 20: VEscapeCT Version 1 -Virtual Escape Room Puzzle 1**	The first puzzle was designed to illustrate the component of decomposition. Four sets of numbers, each containing four digits, were given to the students to analyze. Next to each set, a hint was provided regarding the accuracy of the digits. The aim of this puzzle was to illustrate how decomposition can be used to obtain the correct code	Decomposition

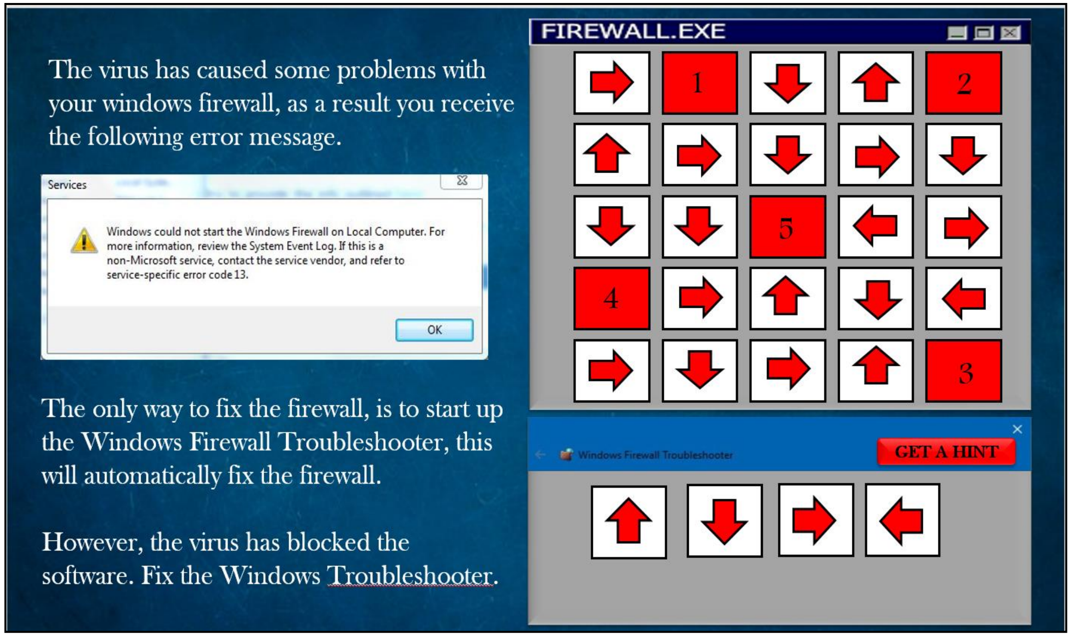
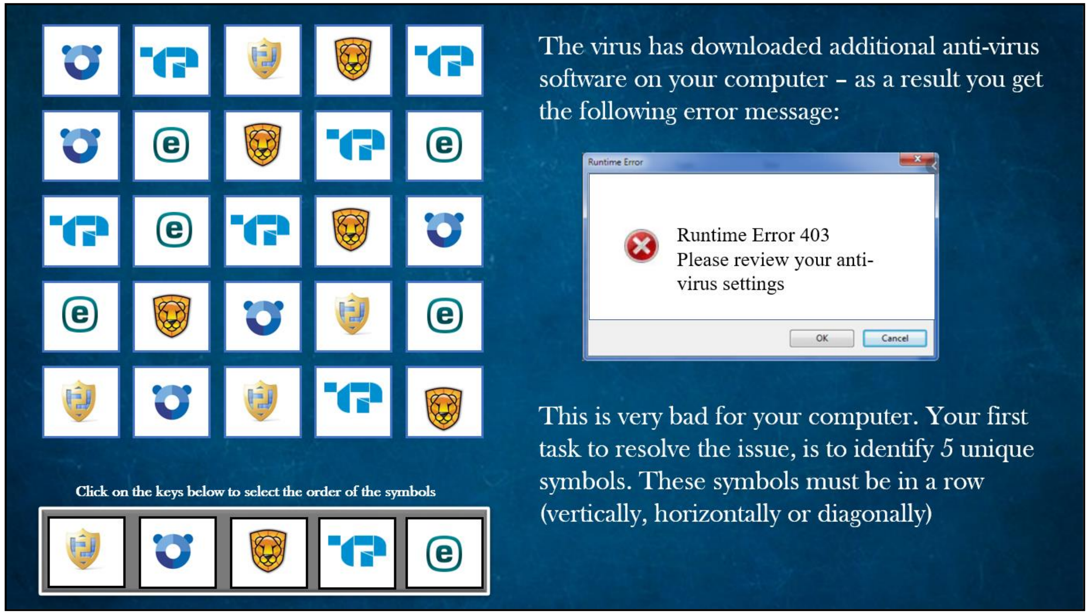
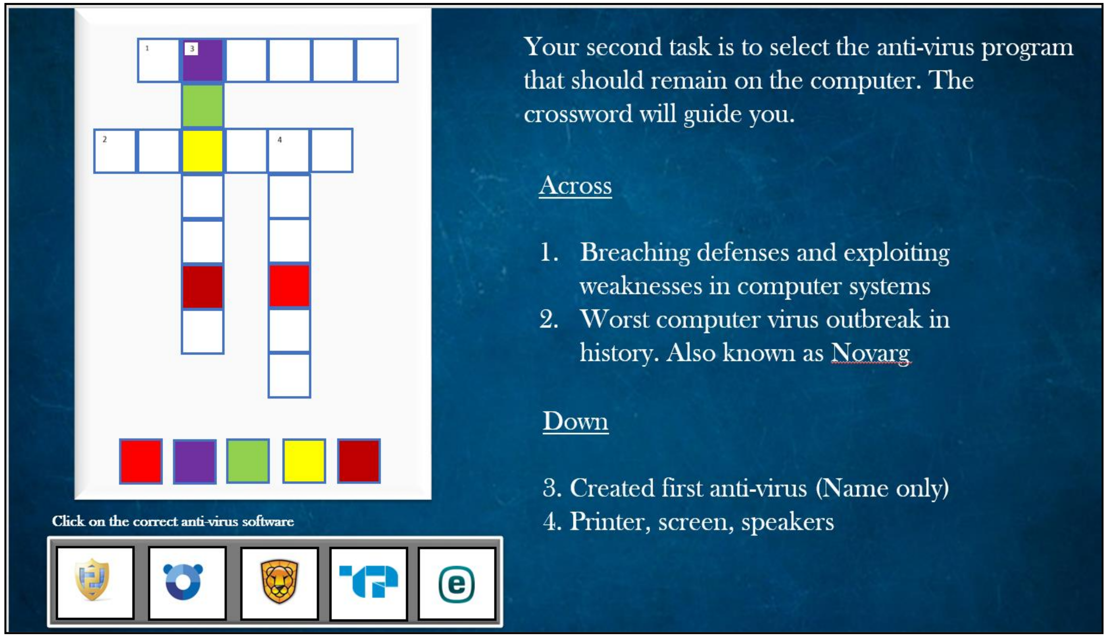
<table>
<tr>
<td>2</td>
<td>


Figure 21: VEscapeCT Version 1 -Virtual Escape Room Puzzle 2
</td>
<td>The second puzzle was designed to illustrate pattern recognition. Students were presented with a diagram that contained arrows. Some of the arrows were left out and students were left with a view of an incomplete pattern. This puzzle required the students to analyze the pattern and then determine which arrows were missing</td>
<td>Pattern Recognition</td>
</tr>
</table>

3	 **Figure 22: VEscapeCT Version 1 -Virtual Escape Room Puzzle 3**	The third puzzle was designed to illustrate the concept of abstraction. Students were presented with a diagram that contained various symbols. Each row of the diagram had a series of symbols. Only one row had a unique series and the students were required to identify this unique row	Abstraction

4	 **Figure 23: VEscapeCT Version 1 -Virtual Escape Room Puzzle 4**	The fourth puzzle was designed to illustrate the concept of decomposition. For this puzzle, students were required to complete a crossword. Certain blocks in the crossword puzzle was highlighted in a different color. The letters in these blocks provided the name of an Anti-Virus Software program that was needed to proceed onto the next level. Students were required to complete the crossword puzzle and then decipher the clue in the highlighted blocks	Decomposition

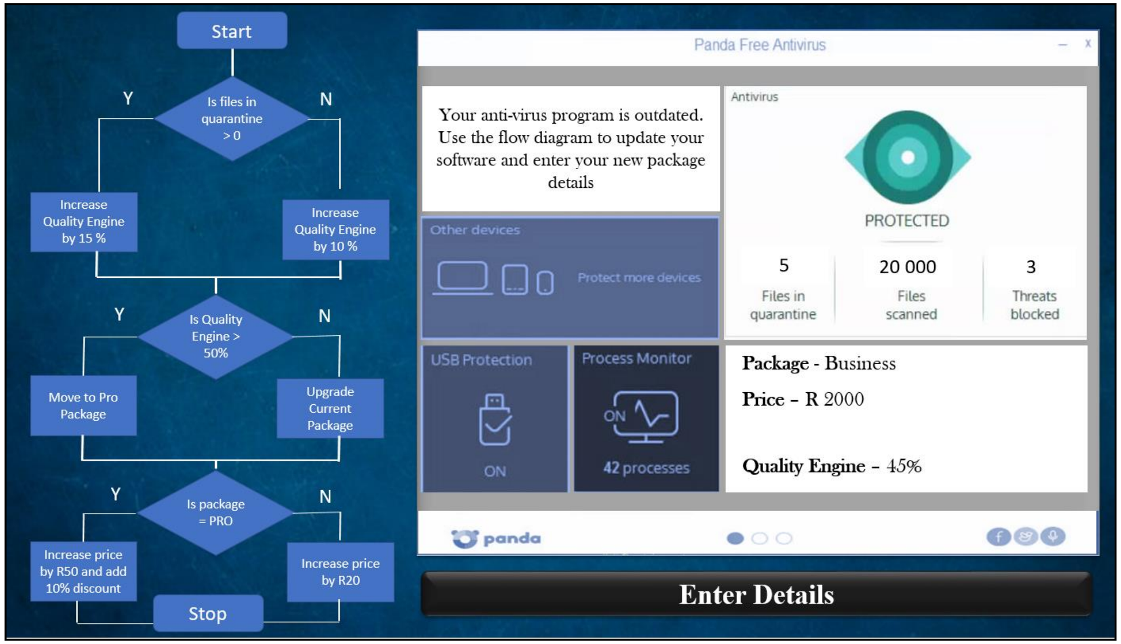
<table>
<tr>
<td>5</td>
<td>

Figure 24: VEscapeCT Version 1 -Virtual Escape Room Puzzle 5</td>
<td>The fifth puzzle was designed to illustrate the concept of algorithmic thinking. Students were provided with an algorithm that they had to use to find the details necessary to activate the anti-virus software.</td>
<td>Algorithmic Thinking</td>
</tr>
</table>

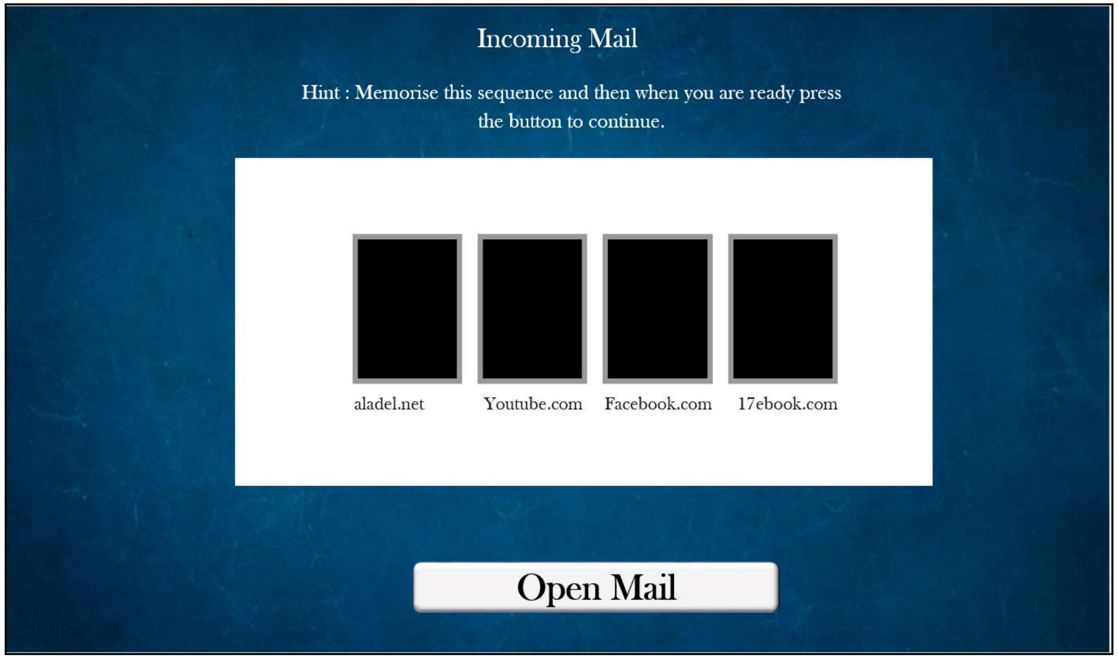
6	 **Figure 25: VEscapeCT Version 1 -Virtual Escape Room Puzzle 6**	The sixth and final puzzle illustrated the concept of pattern recognition. A series of flashing lights appeared on the screen. Students were then required to memorize the pattern within a limited amount of time, and then replicate the pattern in the correct order.	Pattern Recognition

Table 22: Virtual Escape Room Version 1

Upon completing the post-test questionnaire and virtual escape room, the researcher distributed an evaluation form to determine how the respondents experienced the overall process. The evaluation form consisted out of the following three questions:

1. To what extend did the virtual escape room help you to understand computational thinking?
2. To what extend did the virtual escape room improved your attitude towards learning?
3. To what extend did computational thinking help you to understand the planning of a program better?

Two of the questions were aimed at the virtual escape room and how it assisted students in understanding computational thinking and whether the escape room improved their attitude towards learning. The third question was aimed at understanding how computational thinking can be applied within one of the students' course modules. The researcher used the INF 154 module to illustrate how computational thinking can be used to plan a program before students begin with any assignments in the future. As mentioned at the beginning of the chapter, INF 154 is a programming module that Informatics students must take during their first year of study.

The responses to the questions were as follow:

Question 1 - To what extend did the virtual escape room help you to understand computational thinking?

Scale	**Description**	**No of students**
1	To no extent	1
2	To little extent	0
3	To some extent	1
4	To large extent	1
5	To great extent	1

Table 23: Question 1 Evaluation Form (Cycle 1)

Most students indicated that the virtual escape room helped them to understand computational thinking, while the minority indicated that the virtual escape room helped to some extent.

Question 2 - To what extend did the virtual escape room improved your attitude towards learning?

Scale	Description	No of students
1	To no extent	1
2	To little extent	0
3	To some extent	0
4	To large extent	2
5	To great extent	1

Table 24: Question 2 Evaluation Form (Cycle 1)

Most students indicated that the virtual escape room improved their attitude towards learning, while the minority indicated that the virtual escape room only improved their attitude to some extent.

Question 3 - To what extend did computational thinking help you to understand the planning of a program better?

Scale	Description	No of students
1	To no extent	0
2	To little extent	0
3	To some extent	0
4	To large extent	2
5	To great extent	2

Table 25: Question 3 Evaluation Form (Cycle 1)

All four students indicated the computational thinking did help them to understand how to plan a program better.

As a result of the decreased performance by the group of students without INF 113, the researcher revisited the framework by implementing a second cycle of the study.

4.3 SECTION 2: CYCLE 2 DATA ANALYSIS

Based on the findings in the first cycle, the group of students with INF 113 achieved a higher average in the post-test compared to the pre-test, while the group without INF 113 achieved a higher average in the pre-test compared to the post-test. As a result, the researcher revisited the original virtual escape room to identify possible factors contributing to the one group's decreasing performance. The researcher identified the following factors:

1. The puzzles might not have illustrated the components of computational thinking clearly;
2. The narrative of the virtual escape room was aimed at a hacker who planted a virus on a school's computer. The respondents had to stop the virus before it disrupted all the school's computer files. Based on this narrative, the puzzles were all created by incorporating various ways in which one deals with the removal of a computer virus daily. As a result, some of the puzzles might have contained too technical content; therefore, students struggled to understand what they had to do to solve the puzzle. As such, students might have tried any means necessary to solve the puzzle instead of applying the component that was meant to be. Below is an example of some of the puzzle content:

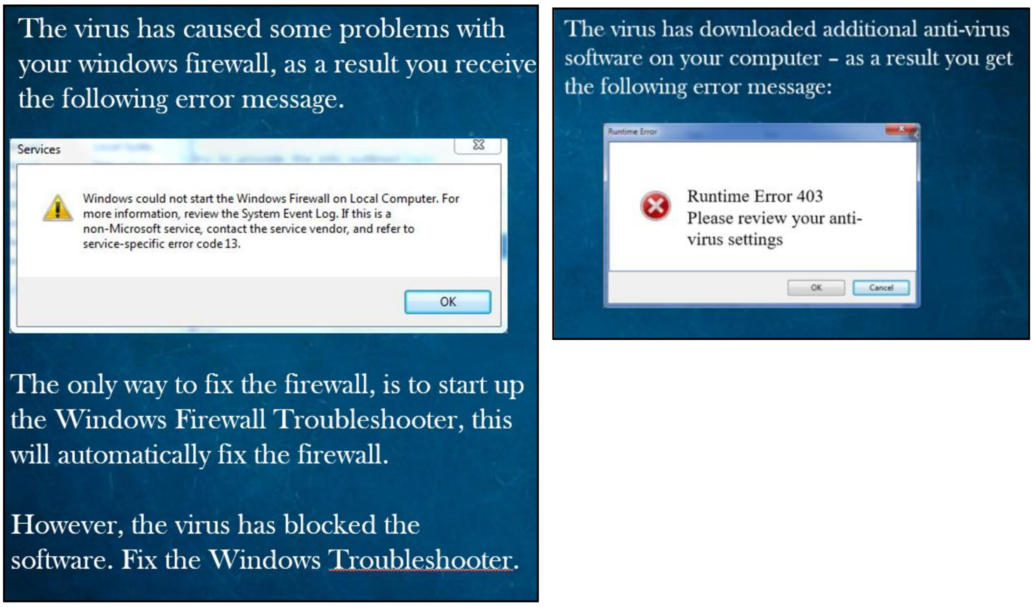


Figure 26: Example error messages found within the virtual escape room

4.3.1 VEscapeCT Framework Version 2

Based on the issues that have been identified during the first round of the study, the researcher revisited the original framework (VEscapeCT) and made the following adjustments to the participates, puzzle and equipment components:

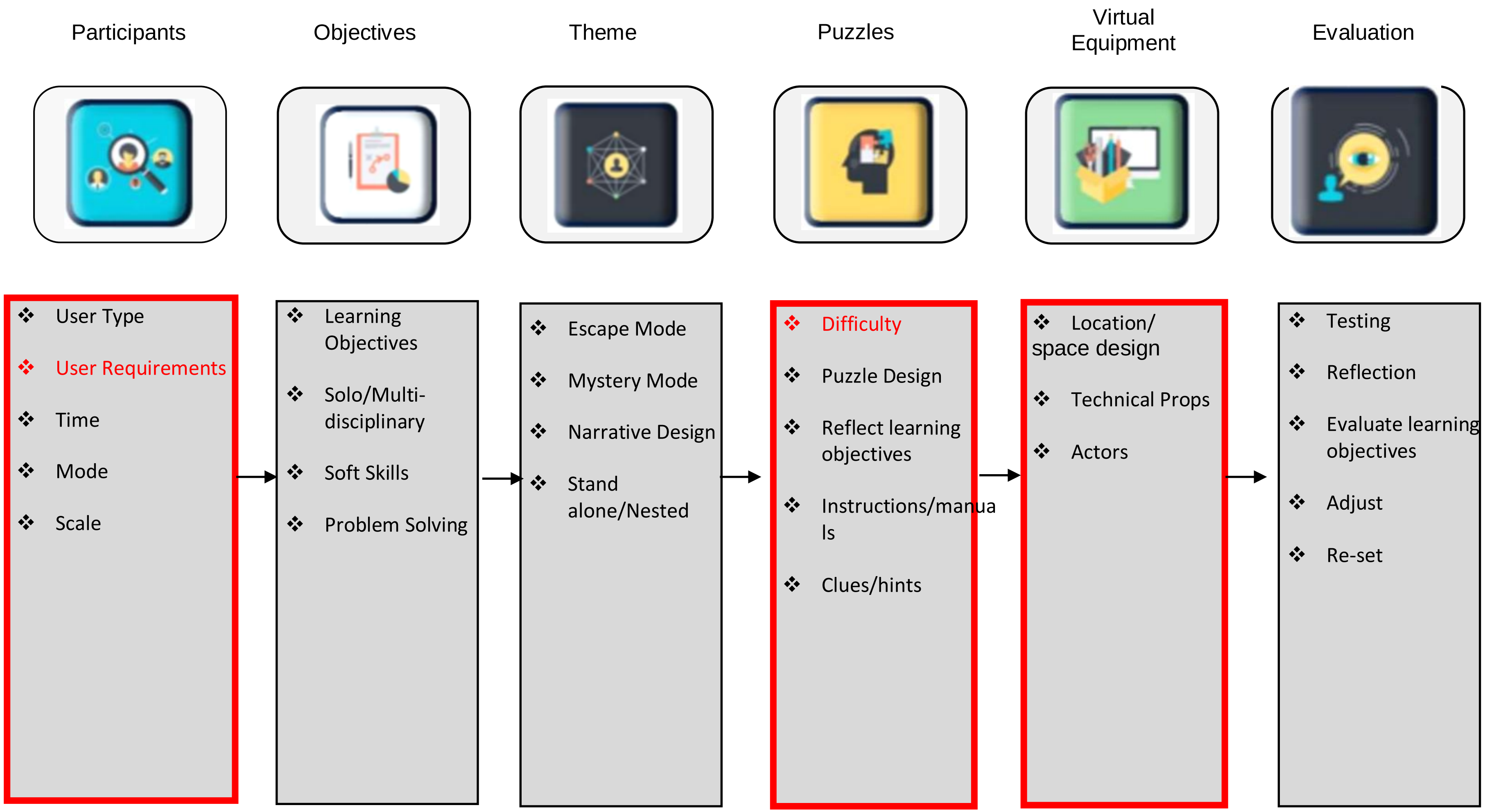


Figure 27: VEscapeCT Framework Version 2 (Adapted from Clarke et al (2017))

Participants

As a result of the technical knowledge required for some of the puzzles, more time should be spent on defining user requirements such as whether prior technical knowledge should be considered a requirement. Based on the aforementioned, the researcher divided the User Type component into User Type and User Requirements. The first area of focus revolves around what type of users will be involved whereas the second area of focus revolves around the background that users should have in order to participate.

Puzzles

The "Difficulty" step should be moved from the Participants section to the Puzzles section in the framework. The researcher determined that it is impossible to decide on a difficulty level at the start of the game. A great escape room is designed with various puzzles, each containing a different difficulty level.

Virtual Equipment

The Equipment section has been renamed to Virtual Equipment and the following component has been removed because it is not applicable to a virtual escape room: physical props.

To evaluate the second version of the VEscapeCT framework, as illustrated above, the researcher interviewed two first-year lecturers from the University of Pretoria to obtain feedback regarding its effectiveness and ability to produce a virtual escape room that can teach computational thinking skills. Appendix E, at the end of the chapter, indicates the interviews' transcripts. A third cycle was implemented for the researcher to analyse the interview responses and implement the necessary changes to the existing virtual escape room.

4.4 SECTION 3: CYCLE 3 DATA ANALYSIS

To analyse the responses from the interviews conducted in the second cycle, the researcher used thematic analysis to identify patterns and themes within the data to summarize and present the data in a meaningful way (see Appendix F for the Themes derived from the interview extracts). Table 26 below presents a summary of the thematic analysis process that was conducted:

Question	Summary	Analysis
1. Looking at the questions set out in the pre-and post-test, would you agree that the questions are sufficient to access a student's computational thinking skills? Please motivate your answer.	The questions encourage higher order thinking	Both lecturers stated that the questions defined in the pre-and post-test are sufficient to test a student's computational thinking skills because the questions are set up on different levels to (1) test whether the student can define each concept, and (2) test whether they can apply that knowledge in an example. It therefore encourages higher order thinking.
2. By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of decomposition?	The question encourages abstraction more than decomposition.	Both lecturers stated that the first puzzle of the virtual escape room did not entirely illustrate the component of decomposition but rather abstraction. Both of the lecturers' motivation was that since students have to go through a process of elimination, in other words, focus on one row at a time and eliminate the numbers that don't match, they only focus on that one particular row, thus ignoring the other rows. It therefore encourages logical thinking since students analyse each row and based on the rows, derive a answer.
3. By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of pattern recognition?	The question encourages pattern recognition.	Both lecturers stated that the second puzzle was apparent regarding the component it represented, which was pattern recognition. Their motivation was that students had to fill in the missing arrows on the diagram, so they had to figure out what the overall pattern was.
4. By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the	The question encourages abstract thinking	Both lecturers stated that the third puzzle was apparent regarding the component it represented, which was abstraction. Their motivation was that students had to go through each row of symbols to find the five unique

component of abstraction?		symbols, thus only focusing on that particular row and ignoring the other rows.
5. By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of decomposition?	The question encourages decomposition and abstraction.	Both lecturers stated that the fourth puzzle was apparent regarding the component it represented, decomposition. An additional comment was made by one of the lecturers that the fourth puzzle illustrated decomposition better than the first puzzle. However, both lecturers also stated that abstraction was involved apart from decomposition. Their motivation regarding decomposition was that students had to break the problem down to solve it. Two steps were identified in the decomposition process: (1) solving the crossword puzzle and (2) using the crossword answers to select the appropriate anti-virus icon. Their motivation for abstraction was that when students searched for the crossword answers, they only focused on the relevant information and not all the information presented
6. By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of algorithmic thinking?	The question encourages algorithmic thinking	Both lecturers stated that the fifth puzzle was apparent regarding the component it represented, algorithmic thinking. Their motivation was that students had to follow the algorithm presented on the screen to find the details necessary to update the anti-virus software.
7. By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of pattern recognition?	The question illustrates pattern recognition	Both lecturers stated that the sixth puzzle was apparent regarding the component it represented, pattern recognition. Their motivation was that students had to follow the pattern of the flashing lights to determine which "mail" to open and which to ignore.
8. In your opinion, what additional support (if any) is required to assist students in completing the computational thinking assessments apart from the virtual	Need for an introductory session	Both lecturers stated that the virtual escape room is a great tool to teach computational thinking because it encourages learning and excitement among students. However, one of the lecturers indicated that it would be beneficial to provide a small introductory lesson at the start of the session to provide a

escape room?		high-level overview of what computational thinking entails, especially for students who have never heard of it.
9. **By examining the suggested VEscapeCT framework below, do you agree with the adjustments made to the framework compared to the original framework shown at the beginning of this interview?**	Revisit user type and difficulty step	Regarding the first adjustment where the User Type is split into User Type and User Requirements, both lecturers disagreed and suggested that it would be more beneficial to keep it one step. However, both lecturers indicated that it is then crucial to perform a detailed analysis of the participants and the prior knowledge they would need before participating in the virtual escape room. Regarding the second adjustment, where the Difficulty step is moved from the Participants to the Puzzle section, both lecturers agreed. Their motivation was: (1) it would be difficult to determine the difficulty levels of the puzzles at the start of the process before the design of the puzzles has commenced, and (2) it would be difficult to determine one level of difficulty. One of the lecturers stated that the puzzles would need to vary in terms of difficulty for an escape room to be challenging.
10. **In your opinion, what other adjustments would you recommend for the VEscapeCT framework to further adjust it to the needs of a virtual escape room?**	Keeping cost in mind	The first lecturer stated that the Location and Actors steps under the Virtual Equipment section need to be removed as it is unnecessary for a virtual escape room. Instead, the Location should be replaced with Platform and Actors with Virtual Actors. The second lecturer stated that adding a Cost section would also be beneficial because students wouldn't want to download software with a price attached to it. Under that step, proper research can then be done into the most cost-effective platform.

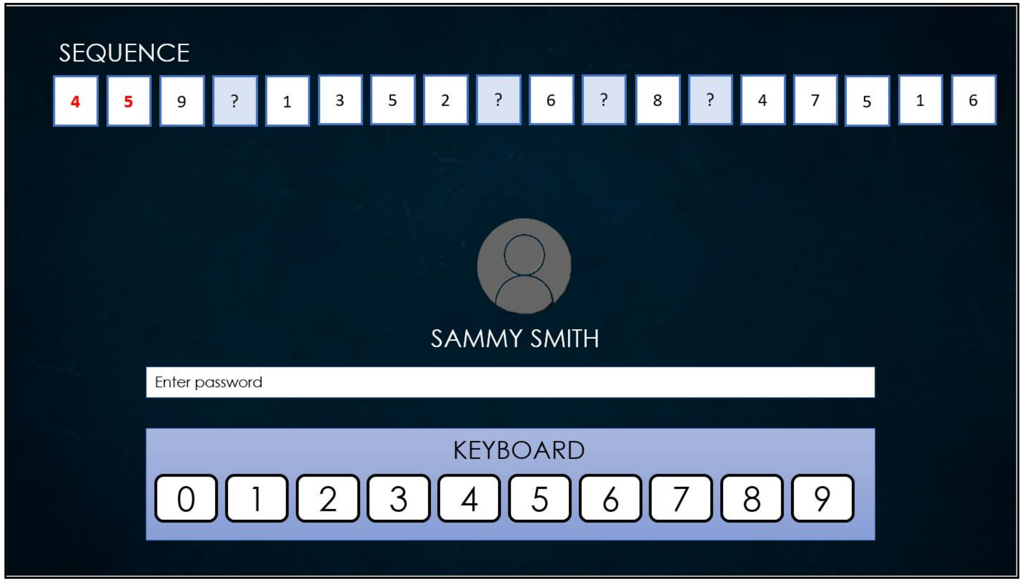
Table 26: Thematic Analysis Summary

Based on the results of the thematic analysis above, the researcher re-designed the virtual escape room. From the above analysis, it is clear that some puzzles test more than one computational thinking component. This is in line with computational thinking problem solving approaches, as it always involves most of the components.

4.4.1 New Virtual Escape Room

The theme of the virtual escape room still revolved around removing computer viruses; however, the researcher simplified the content compared to the first virtual escape room. The narrative was as follows: A student received an assignment in one of his modules. This assignment was handed out a few weeks ago; however, the due date was set to be the following day. As usual, the student only starts with the assignment the day before it is due but soon realizes there will not be enough time to finish it. The student calls one of his friends to assist, and they agree. The friend hands over a flash drive with all the necessary information that will help the student to complete the assignment in time; however, the student's computer suddenly starts to shut down upon submitting the assignment. The student suddenly receives a notification from his friend informing him that there was a virus on the flash drive. The student quickly found a way to turn his computer back on and immediately performed the following steps to ensure that the virus that was transferred to his computer was removed:

- Turning on the firewall
- Updating the anti-virus software
- Running a scan of all the files located on the computer
- Removing all the files that were copied over from the flash drive to the computer

Puzzle	Component	Description
 **Figure 28: VEscapeCT Version 2-Virtual Escape Room Puzzle 1**	Pattern Recognition	The first puzzle was designed to illustrate the concept of pattern recognition. Students were presented with a partially completed pattern which they were instructed to complete. The missing numbers formed the new login details

<table>
<tr>
<td>

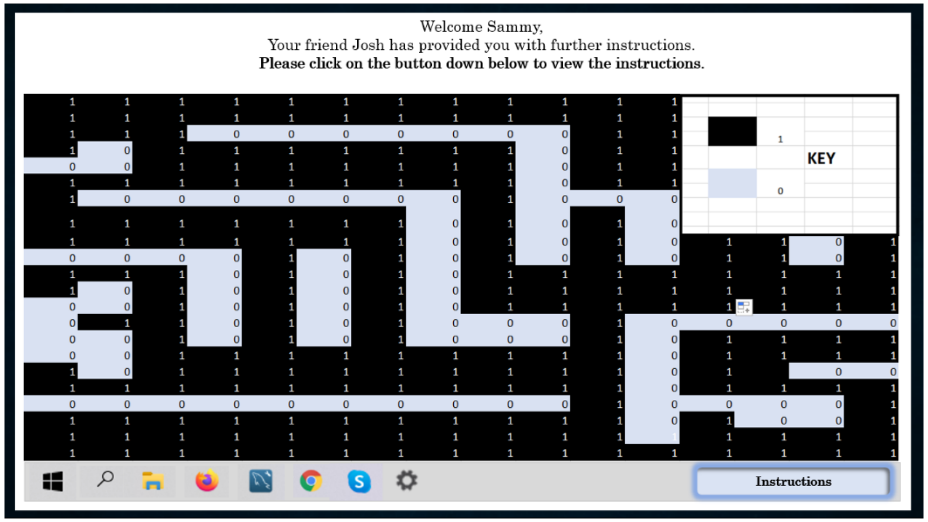


Figure 29: VEscapeCT Version 2-Virtual Escape Room Puzzle 2

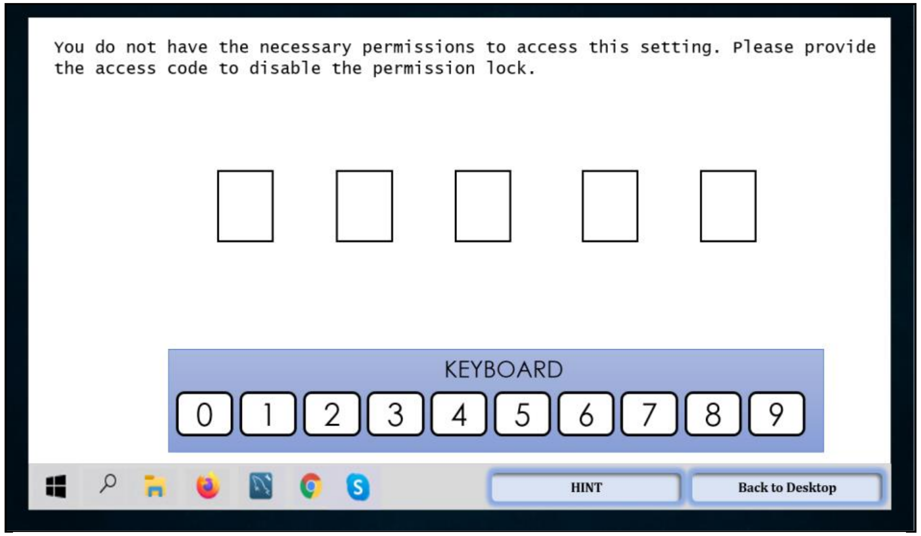
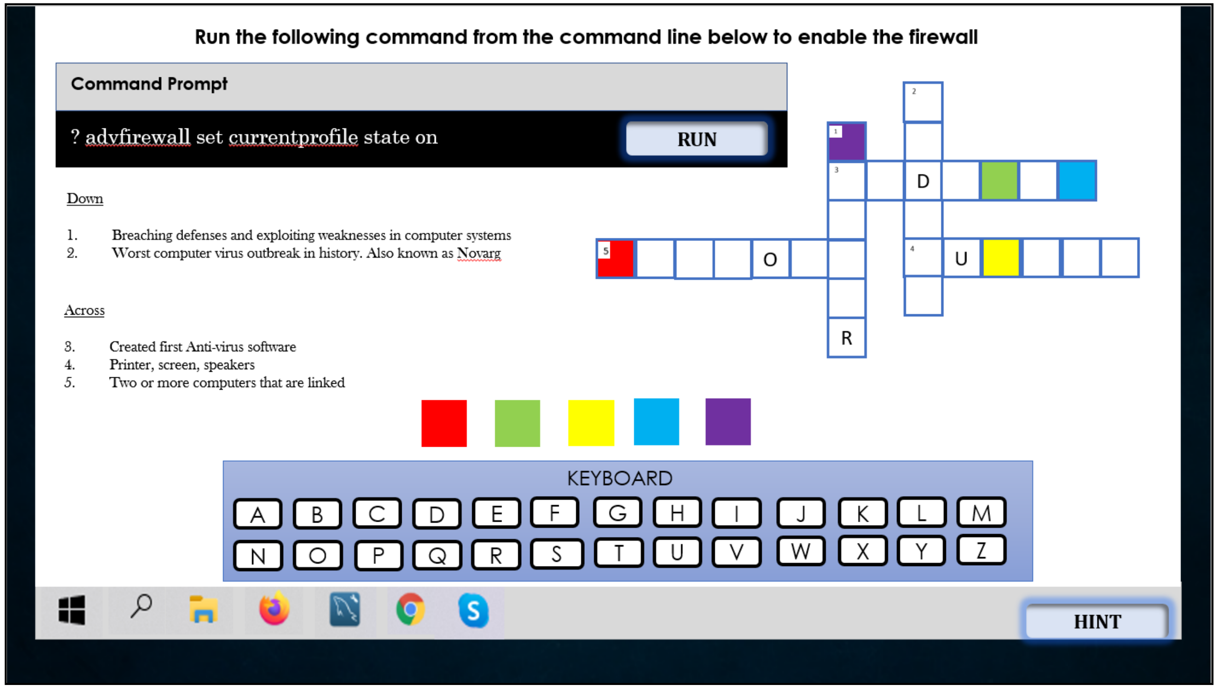


Figure 30: VEscapeCT Version 2-Virtual Escape Room Puzzle 2

</td>
<td>Abstraction</td>
<td>The second puzzle was designed to illustrate the concept of abstraction. Students had to use the screen illustrated in Figure 35 to find the code necessary to solve the puzzle illustrated in Figure 36..</td>
</tr>
</table>

 **Figure 31: VEscapeCT Version 2-Virtual Escape Room Puzzle 3**	Decomposition and abstraction	The third puzzle was designed to illustrate the concept of decomposition and abstraction. For this puzzle, students were required to complete a crossword. Certain blocks in the crossword puzzle was highlighted in a different color. The letters in these blocks provided the missing command necessary to run the firewall. Students were required to complete the crossword puzzle and then decipher the clue in the highlighted blocks.

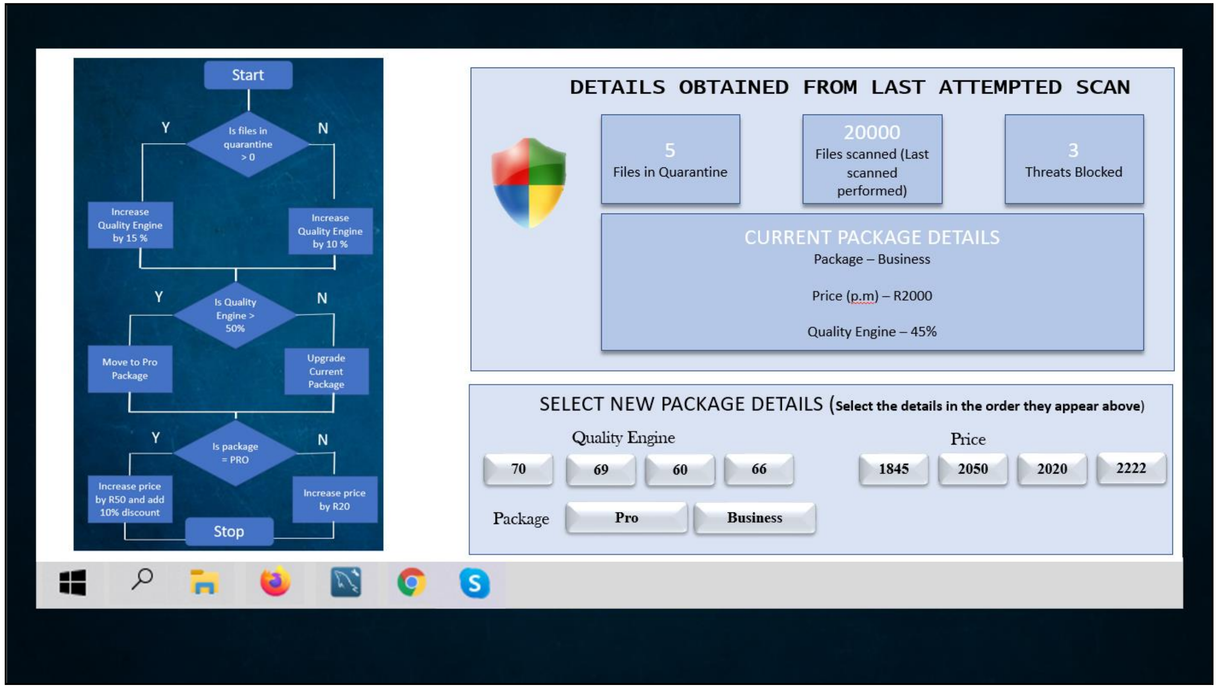
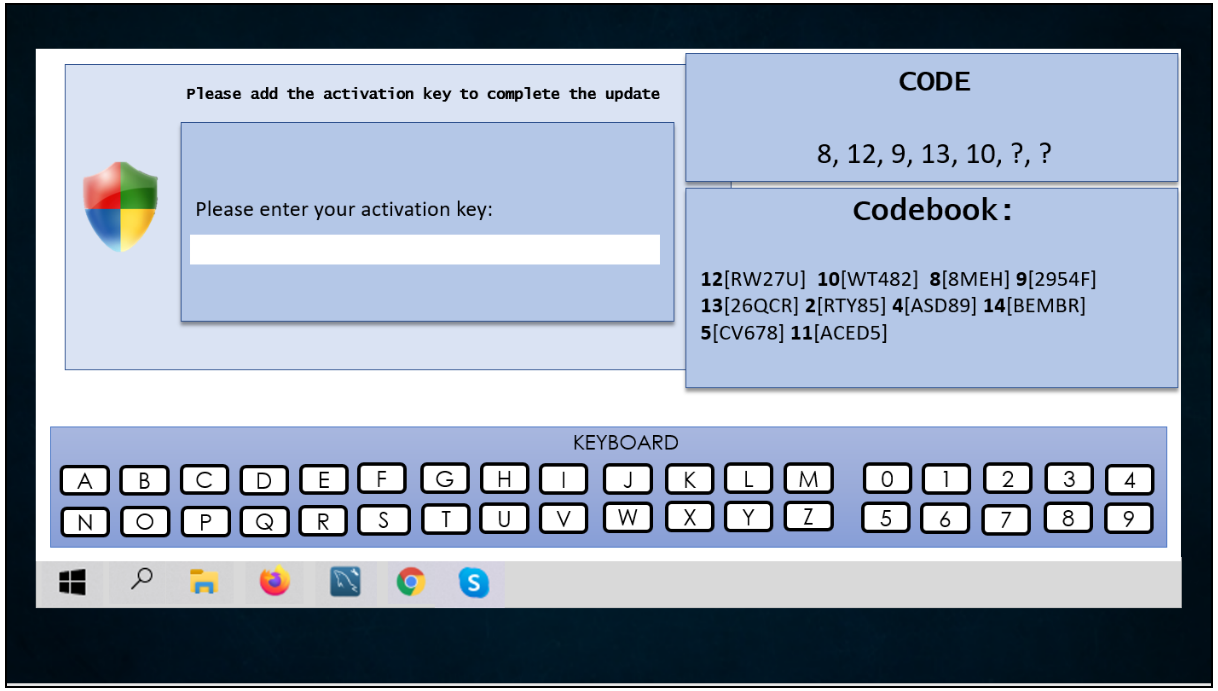
<table>
<tr>
<td>

Figure 32: VEscapeCT Version 2-Virtual Escape Room Puzzle 4</td>
<td>Algorithmic Thinking</td>
<td>The fourth puzzle was designed to illustrate the concept of algorithmic thinking. Students were provided with an algorithm that they had to use to find the details necessary to activate the anti-virus software.</td>
</tr>
</table>

 **Figure 33: VEscapeCT Version 2-Virtual Escape Room Puzzle 5**	Pattern Recognition and Decomposition	The fifth puzzle was designed to illustrate the component of pattern recognition and decomposition. Students were presented with a partially completed pattern that had to be completed first. After that, students had to use the code book to determine what the ant-virus software product key is.

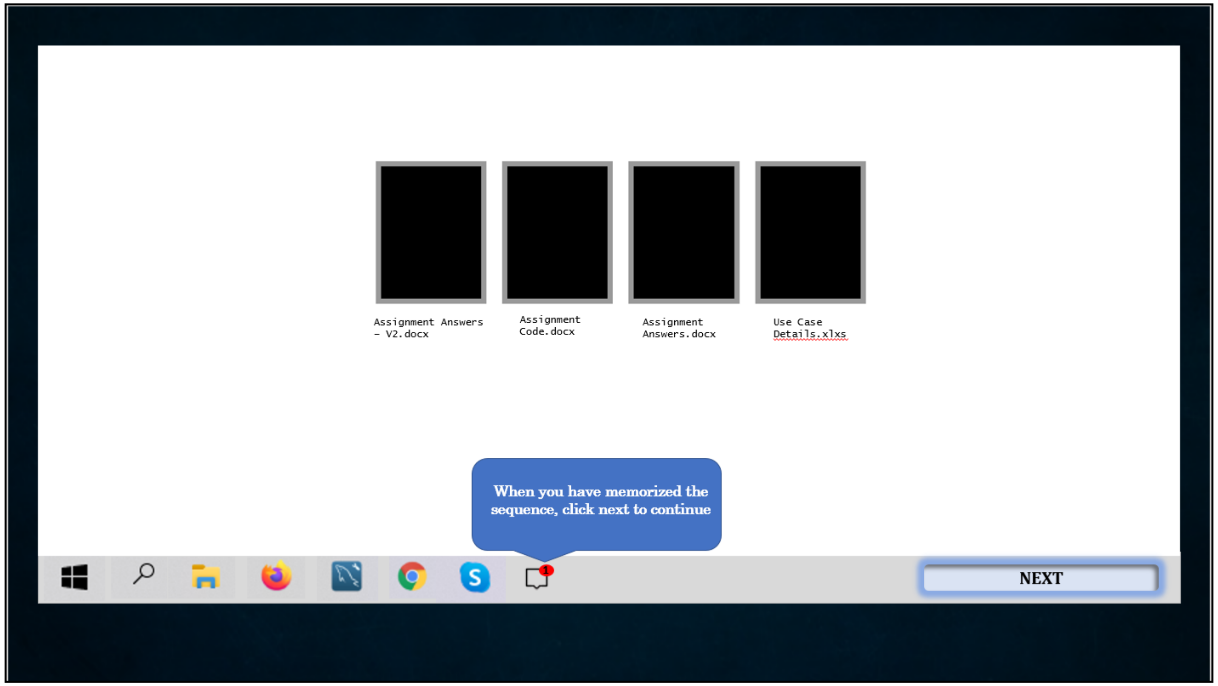
 **Figure 34: VEscapeCT Version 2-Virtual Escape Room Puzzle 6**	Pattern Recognition	The sixth and final puzzle was designed to illustrate the concept of pattern recognition. Students were presented with a series of flashing lights in which they had to memorize the sequence. The sequence illustrated what files to remove from the computer and in what order. The students had to then repeat the pattern.

Table 27: Virtual Escape Room Version 2

4.4.2 Pre- and Post-Test Questionnaires

A total of eighty-two students participated during the third cycle of the study, of which only sixty-two students' data were usable (n = 62), thus resulting in a 75,61% response rate. As illustrated in Chapter 3, participants included first-year students from the University of Pretoria. The cycle commenced during an online INF 164 lecture session; there are thus various factors that may contribute to the low response rate of the study:

- The session was not mandatory for the students.
- The activities didn't contribute towards any marks in the module.
- There were no incentives for completing the activities.

The participants each had to complete the following activities within the first cycle: pre-test, virtual escape room, and post-test. The analysis of each of these activities is presented below:

4.4.2.1. Pre- and Post-Test Questionnaire Results

Both the pre-and post-test questionnaire was loaded onto Google Forms because it provided the researcher with immediate access to the responses as the respondents filled in the questionnaires and additional reporting capabilities. A link was emailed to the respondents that they had to use in order to access the questionnaire. It both consisted of 12 multiple-choice questions, each representing one of the components of computational thinking described in Chapter 3. The findings of the questionnaires are discussed in more detail in section 4.4.2.1.1 below.

4.4.2.1.1. Data Analysis

To represent the findings of the questionnaires received, the researcher used the same key as explained in APPENDIX H to transform the answers into a set of meaningful data that can be presented in a table and graph.

The feedback obtained through the questionnaires was subjected to frequency counts; in other words, the responses for each question were added together to find the highest frequency of occurrence (i.e., the number of times a particular response occurs). The responses for each question were then categorized according to students with and without INF 113 as a module.

The following legends were used to identify students with and without computational thinking:

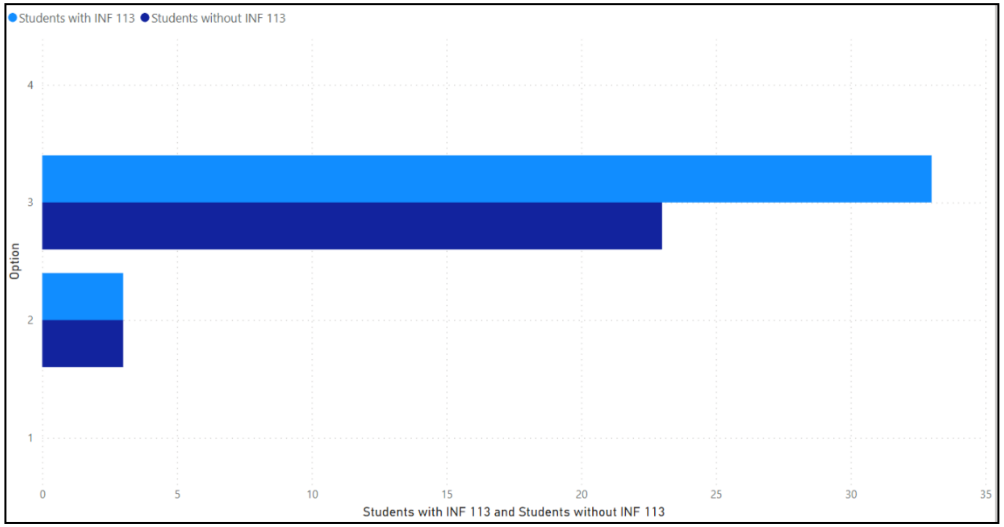
● Students with INF 113 ● Students without INF 113

The y-axis represent the answer selected by the student where the x-axis represents the total number of students.

Question 1: What is Computational Thinking?

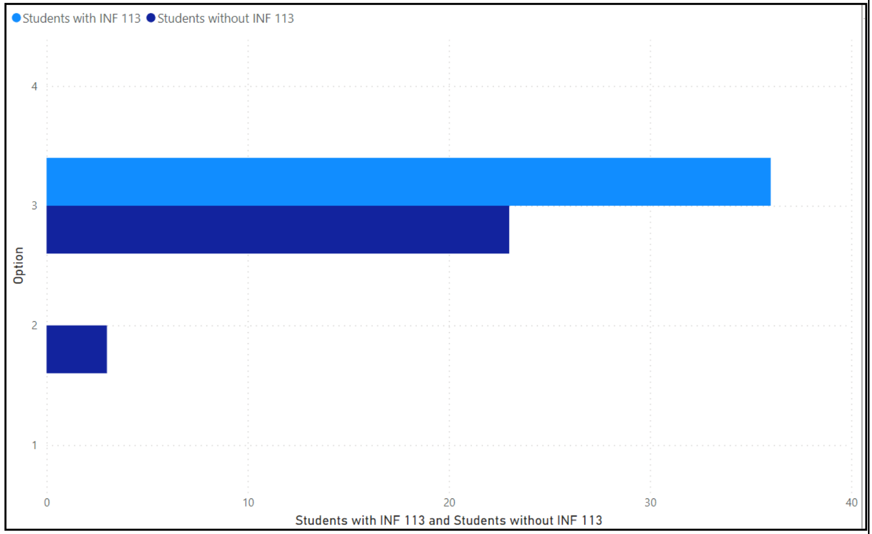
The first question sought to identify whether respondents could demonstrate a basic understanding of computational thinking by identifying the correct definition for computational thinking.

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = The way computers think	-	-	
2 = A problem-solving approach that **only** computer scientists use, that involves expressing problems in a way that	6	10	

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = The way computers think	-	-	
2 = A problem-solving approach that **only** computer scientists use, that involves expressing	3	5	

computers can understand			
3 = A problem-solving approach that can be used by anyone, that involves expressing problems in a way that computers can understand	56	90	☑
4 = The way computers follow instructions	-	-	

Based on the results above, 56 (90%) of the respondents identified the correct answer, while 6 (10%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	92	8
Respondents without INF 113	26	88	12

problems in a way that computers can understand			
3 = A problem-solving approach that can be used by anyone, that involves expressing problems in a way that computers can understand	59	95	☑
4 = The way computers follow instructions	-	-	

Based on the results above, 59 (95%) of the respondents identified the correct answer, while 3 (5%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	100	-
Respondents without INF 113	26	88	12

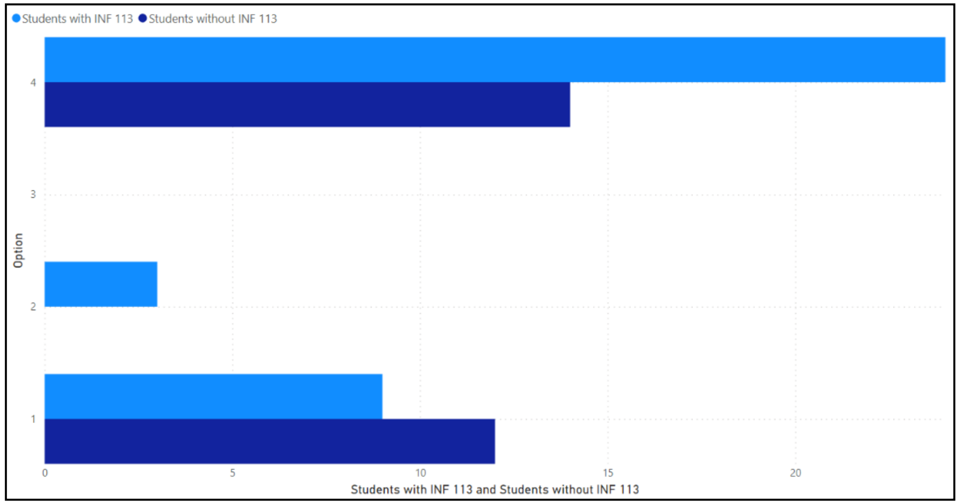
Table 28: What is Computational Thinking? (Cycle 3)

Question 2: Which of the following is an example of computational thinking?

The second question sought to identify whether respondents could use the definition of computational thinking to identify an example in which computational thinking can be applied.

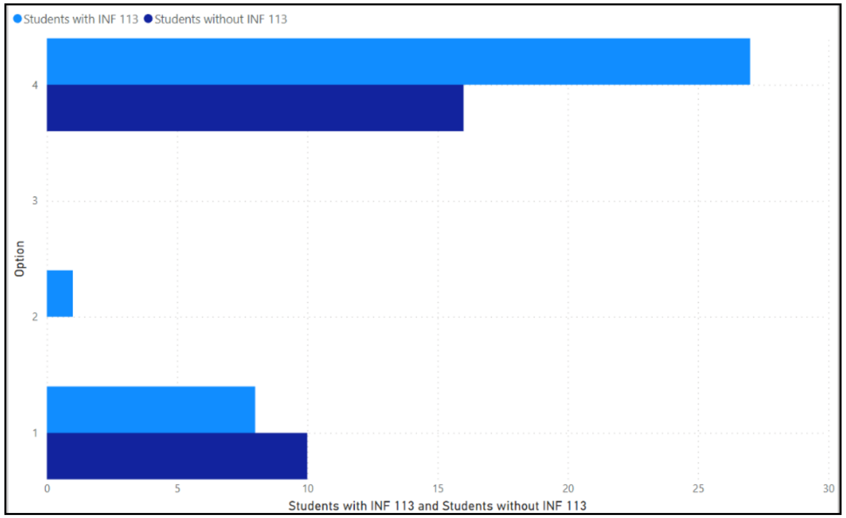
Pre-Test	Post-Test

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Sorting of important documents	21	34	
2 = Choosing a line at the supermarket	3	5	
3 = Running Errands	-	-	

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Sorting of important documents	18	29	
2 = Choosing a line at the supermarket	1	2	
3 = Running Errands	-	-	

4 = All of the above	38	61	☑

Based on the results above, 38 (61%) of the respondents identified the correct answer, while 24 (39%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	67	33
Respondents without INF 113	26	54	46

4 = All of the above	43	69	☑

Based on the results above, 43 (69%) of the respondents identified the correct answer, while 19 (31%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

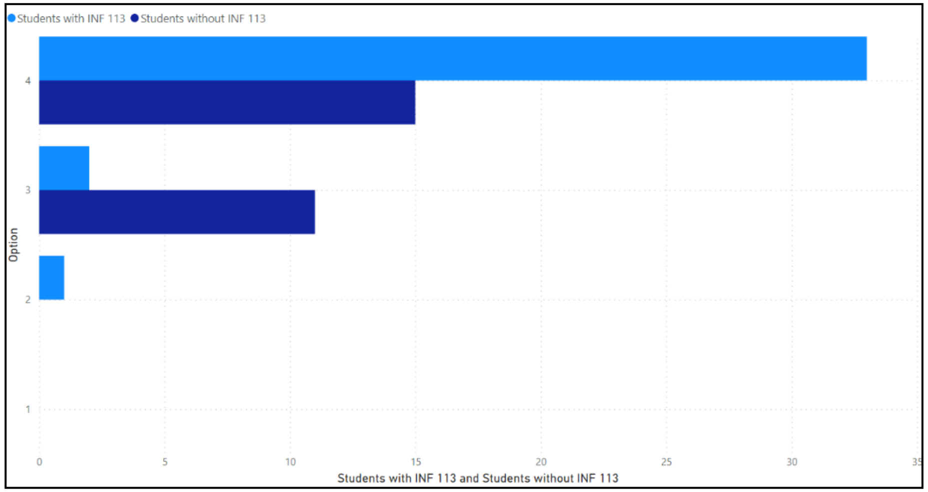
Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	75	25
Respondents without INF 113	26	62	38

Table 29: Which of the following is an example of computational thinking? (Cycle 3)

Question 3: In which of the following disciplines can computational thinking be applied?

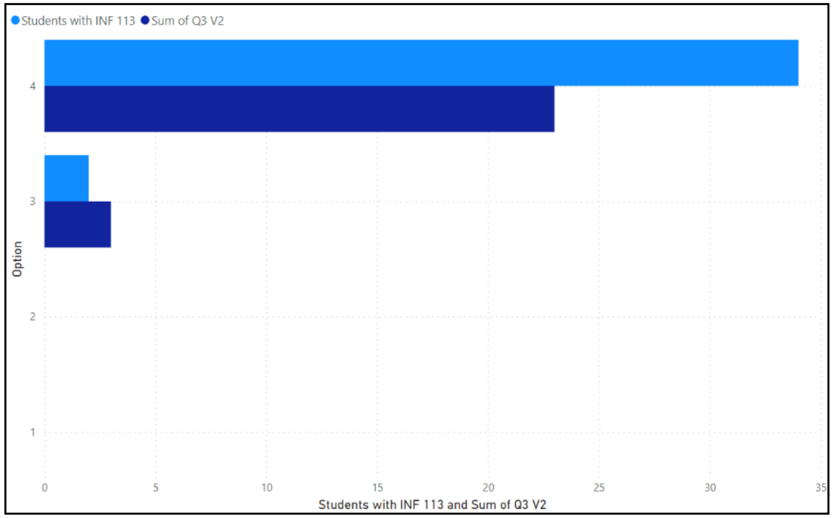
The third question sought to identify whether respondents could further apply the concept of computational thinking by identifying a discipline in which computational thinking can be used.

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = English Literature	-	-	
2 = Mathematics	1	2	

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = English Literature	-	-	
2 = Mathematics	-	-	

3 = Computer Science	13	21	
4 = All of the above	48	77	☑

Based on the results above, 48 (77%) of the respondents identified the correct answer, while 14 (23%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	92	8
Respondents without INF 113	26	58	42

3 = Computer Science	5	8	
4 = All of the above	57	92	☑

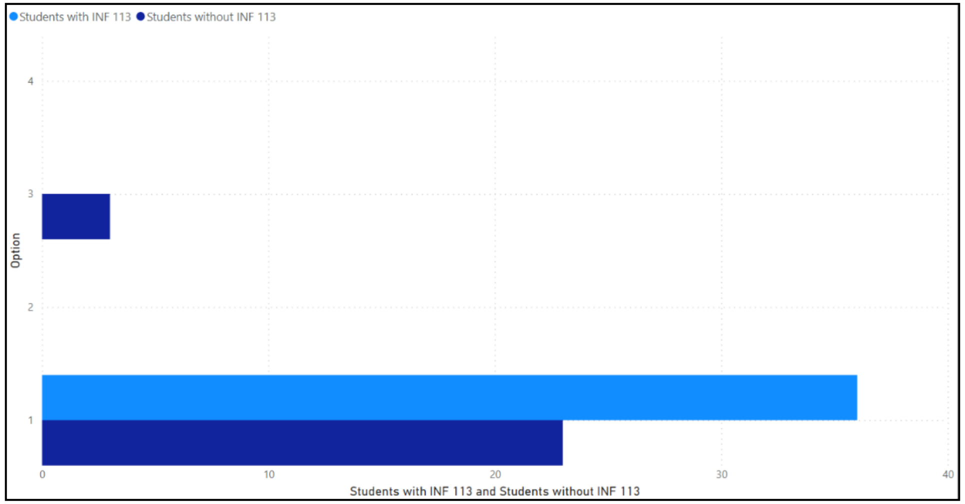
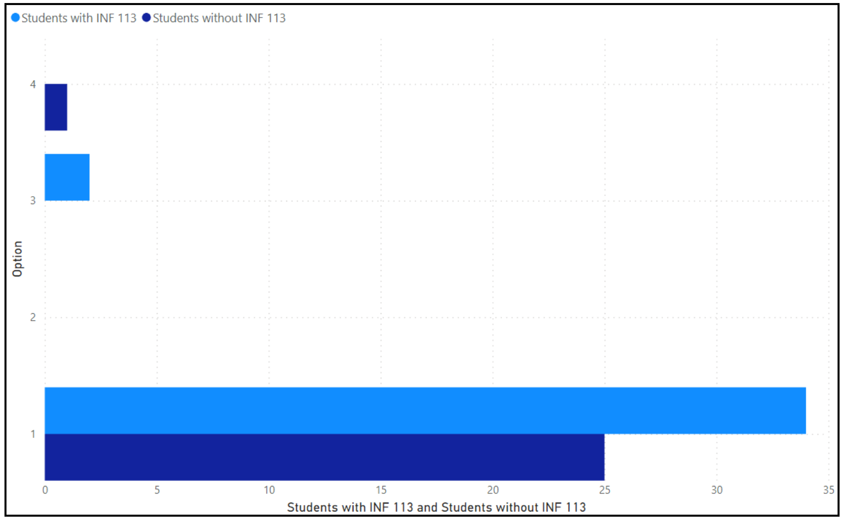
Based on the results above, 57 (92%) of the respondents identified the correct answer, while 5 (8%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	94	6
Respondents without INF 113	26	88	12

Table 30: In which of the following disciplines can computational thinking be applied? (Cycle 3)

Question 4: What is decomposition?

The fourth question sought to identify whether respondents could demonstrate a basic understanding of decomposition by identifying the correct definition for decomposition

Pre-Test	Post-Test
	

Pre-Test

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Breaking a big problem into smaller problems that are easier to solve	59	95	☑

Post-Test

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Breaking a big problem into smaller problems that are easier to solve	59	95	☑

2 = Removing necessary details in a problem	-	-	
3 = Breaking a big problem into smaller problems that challenges our way of thinking	3	5	
4 = Removing unnecessary details in a problem	-	-	

Based on the results above, that 59 (95%) of the respondents identified the correct answer, while 3 (5%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	100	-
Respondents without INF 113	26	88	12

2 = Removing necessary details in a problem	-	-	
3 = Breaking a big problem into smaller problems that challenges our way of thinking	2	3	
4 = Removing unnecessary details in a problem	1	2	

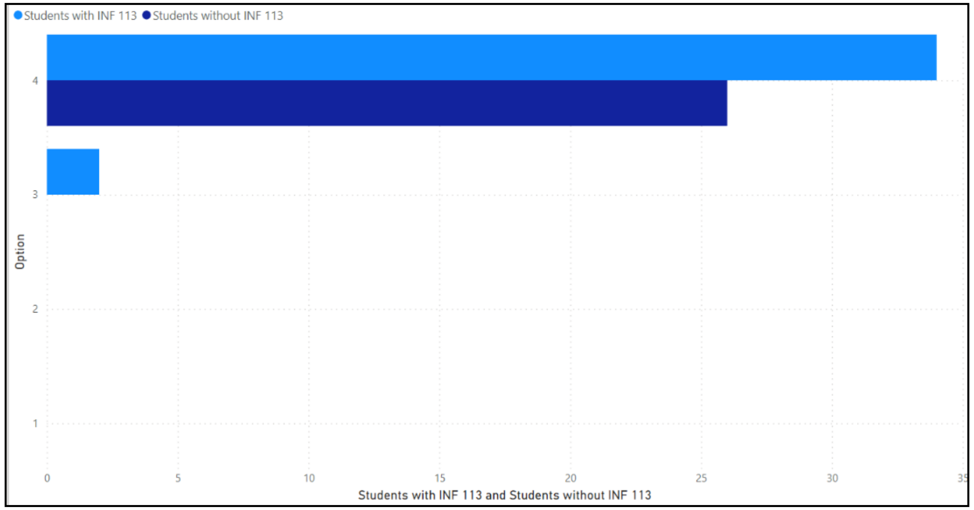
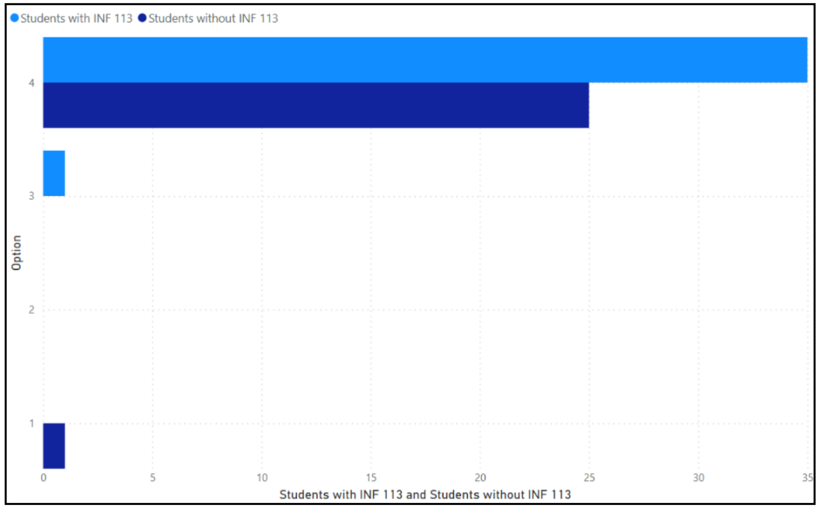
Based on the results above, 59 (95%) of the respondents identified the correct answer, while 3 (5%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	94	6
Respondents without INF 113	26	96	4

Table 31: What is decomposition? (Cycle 3)

Question 5: What is an example of decomposition?

The fifth question sought to identify whether respondents could apply the definition of decomposition by identifying the correct example in which decomposition can be used.

Pre-Test	Post-Test
	

Pre-Test

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Baking a cake	-	-	
2 = Looking at what different kind of cakes	-	-	

Post-Test

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Baking a cake	1	2	
2 = Looking at what different kind of cakes	-	-	

can be made			
3 = Thinking about how we can make it the best cake	2	3	
4 = When baking a cake, thinking about what ingredients to get together, what the method is and how the cake should be decorate	60	97	☑

Based on the results above, 60 (97%) of the respondents identified the correct answer, while 2 (3%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	94	6
Respondents without INF 113	26	100	-

can be made			
3 = Thinking about how we can make it the best cake	1	2	
4 = When baking a cake, thinking about what ingredients to get together, what the method is and how the cake should be decorate	60	96	☑

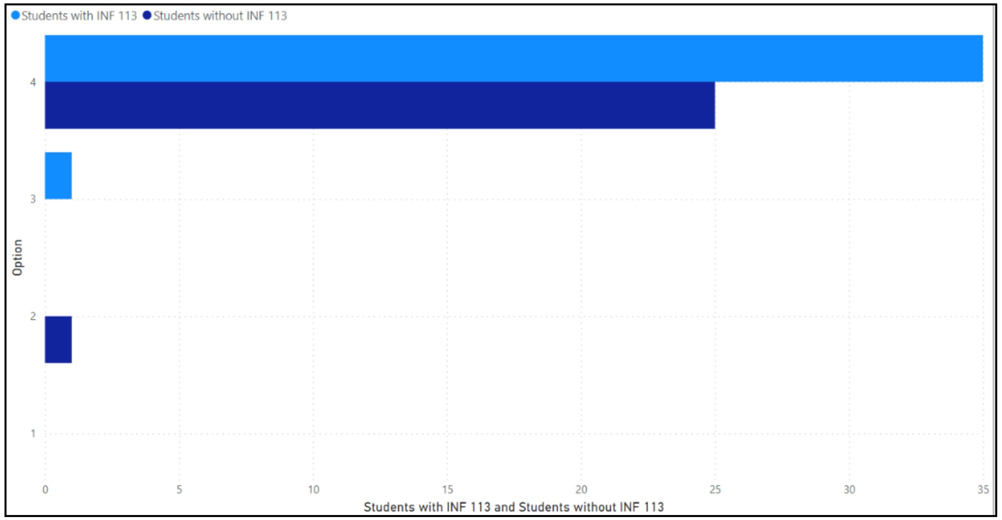
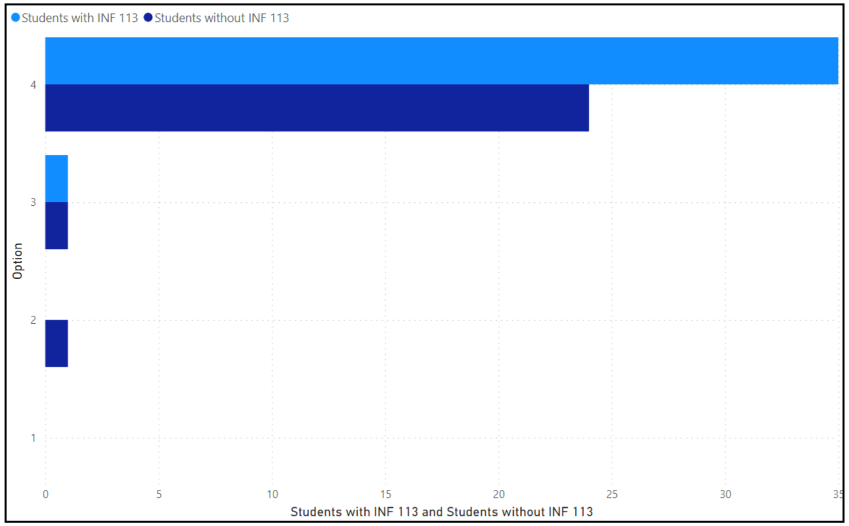
Based on the results above, 60 (96%) of the respondents identified the correct answer, while 2 (4%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	94	6
Respondents without INF 113	26	96	4

Table 32: What is an example of decomposition? (Cycle 3)

Question 6: What is pattern recognition?

The sixth question sought to identify whether respondents could demonstrate a basic understanding of pattern recognition by identifying the correct definition for pattern recognition.

Pre-Test	Post-Test
 	

Pre-Test

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Removing unnecessary details from a problem	-	-	

Post-Test

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Removing unnecessary details from a problem	-	-	

2 = Identifying differences in problems	1	.1.5		**2** = Identifying differences in problems	1	2	
3 = Removing unnecessary details from a problem	1	1.5		**3** = Removing unnecessary details from a problem	2	3	
4 = Identifying similarities in problems	60	97	☑	**4** = Identifying similarities in problems	59	95	☑

Based on the results above, 60 (96%) of the respondents identified the correct answer, while 2 (3%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	97	3
Respondents without INF 113	26	96	4

Based on the results above, 59 (95%) of the respondents identified the correct answer, while 3 (5%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

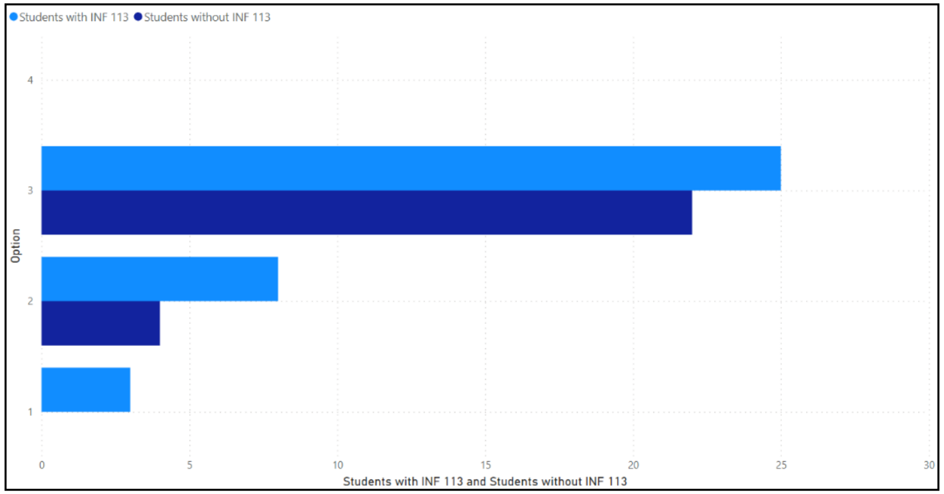
Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	97	3
Respondents without INF 113	26	92	8

Table 33: What is pattern recognition? (Cycle 3)

Question 7: What is an example of pattern recognition?

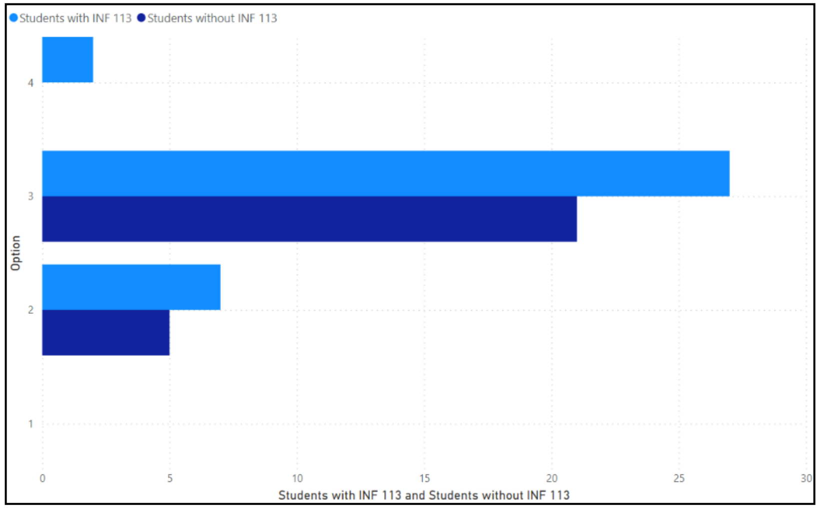
The seventh question sought to identify whether respondents could apply the definition of pattern recognition by identifying the correct example in which pattern recognition can be used.

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Uploading a photo to Facebook	3	5	
2 = Facebook's Location Services	12	19	

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Uploading a photo to Facebook	-	-	
2 = Facebook's Location Services	12	19	

3 = Facebook's Facial Recognition	47	76	☑
4 = Uploading a photo to Instagram	-	-	

Based on the results above, 47 (76%) of the respondents identified the correct answer, while 15 (24%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	69	31
Respondents without INF 113	26	84	16

3 = Facebook's Facial Recognition	48	78	☑
4 = Uploading a photo to Instagram	2	3	

Based on the results above, 48 (78%) of the respondents identified the correct answer, while 14 (22%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

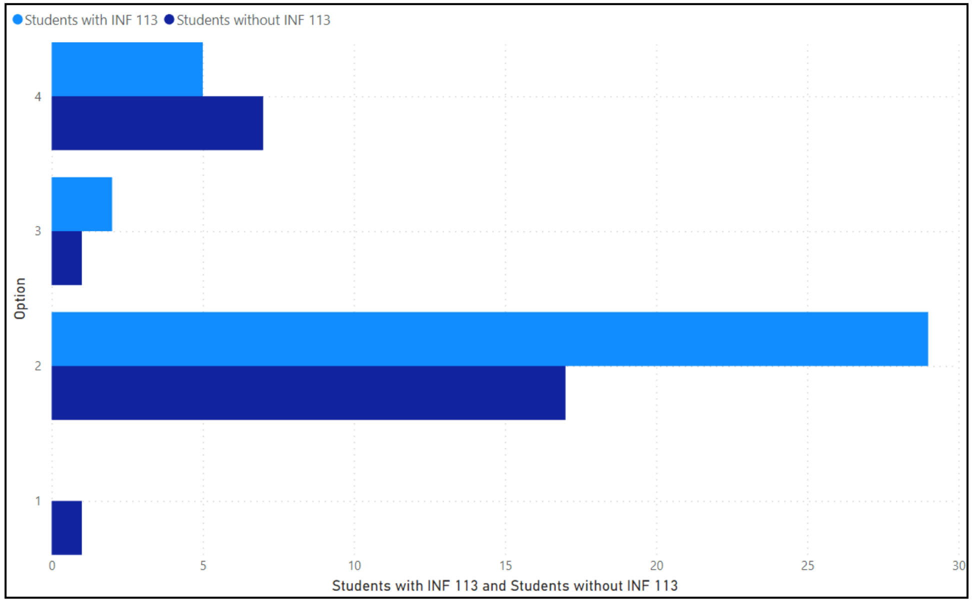
Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	75	25
Respondents without INF 113	26	80	20

Table 34: What is an example of pattern recognition? (Cycle 3)

Question 8: What is abstraction?

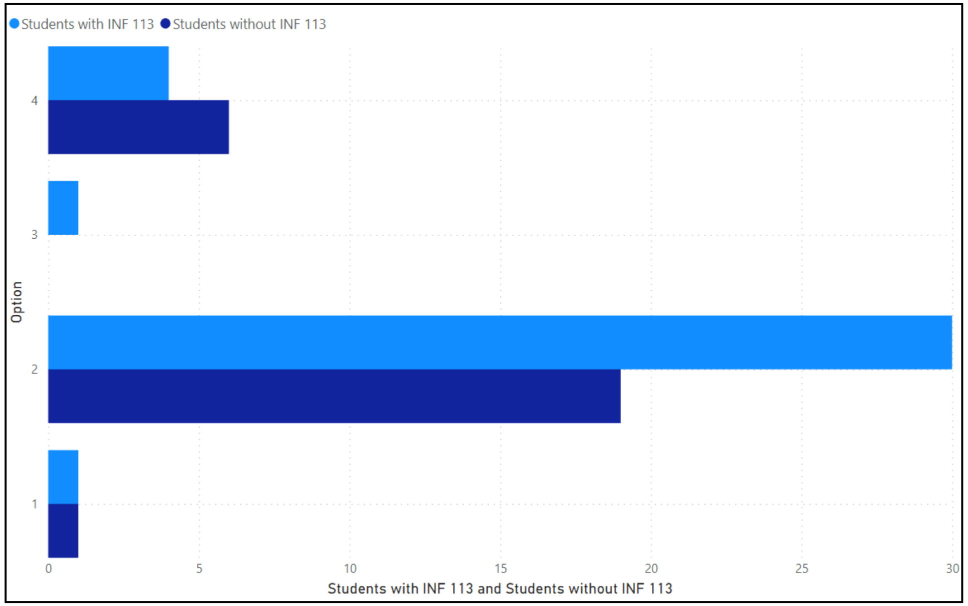
The eighth question sought to identify whether respondents could demonstrate a basic understanding of abstraction by identifying the correct definition for abstraction.

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Drawing conclusions from problems by	1	2	

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Drawing conclusions from problems by	2	3	

applying abstract thinking			
2 = Simplifying a problem by only dealing with the important details and neglecting the unnecessary details	46	74	☑
3 = Simplifying a problem by only dealing with the unimportant details and neglecting the necessary details	3	5	
4 = Drawing important details from problems by applying abstract thinking	12	19	

Based on the results above, 46 (74%) of the respondents identified the correct answer, while 16 (26%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	81	19
Respondents without INF 113	26	65	35

applying abstract thinking			
2 = Simplifying a problem by only dealing with the important details and neglecting the unnecessary details	49	79	☑
3 = Simplifying a problem by only dealing with the unimportant details and neglecting the necessary details	1	2	
4 = Drawing important details from problems by applying abstract thinking	10	16	

Based on the results above, 49 (79%) of the respondents identified the correct answer, while 13 (21%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

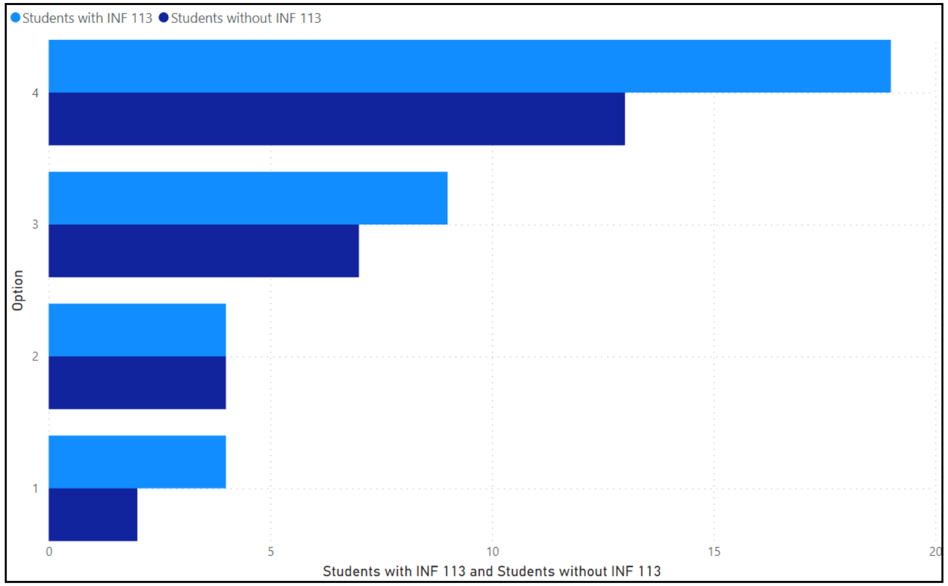
Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	83	17
Respondents without INF 113	26	73	27

Table 35: What is abstraction? (Cycle 3)

Question 9: What is an example of abstraction?

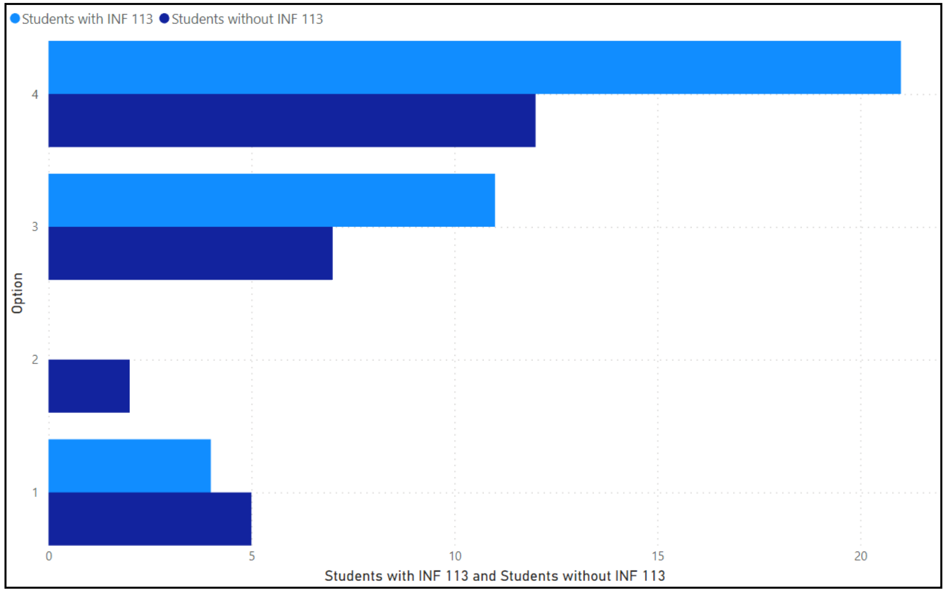
The ninth question sought to identify whether respondents could apply the definition of abstraction by identifying an example in which abstraction can be used.

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = A Map	6	9	

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = A Map	9	15	

2 = A house plan	8	13	
3 = A sign of an isle store	16	26	
4 = All of the above	32	52	☑

Based on the results above, 32 (52%) of the respondents identified the correct answer, while 30 (48%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	53	47
Respondents without INF 113	26	50	50

2 = A house plan	2	3	
3 = A sign of an isle store	18	29	
4 = All of the above	33	53	☑

Based on the results above, 33 (53%) of the respondents identified the correct answer, while 29 (47%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

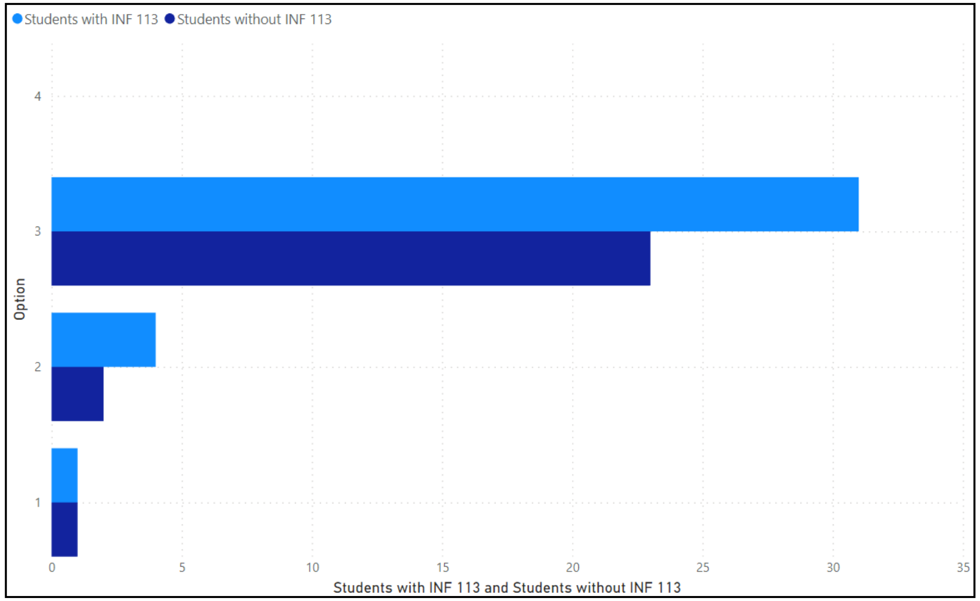
Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	58	42
Respondents without INF 113	26	46	54

Table 36: What is an example of abstraction? (Cycle 3)

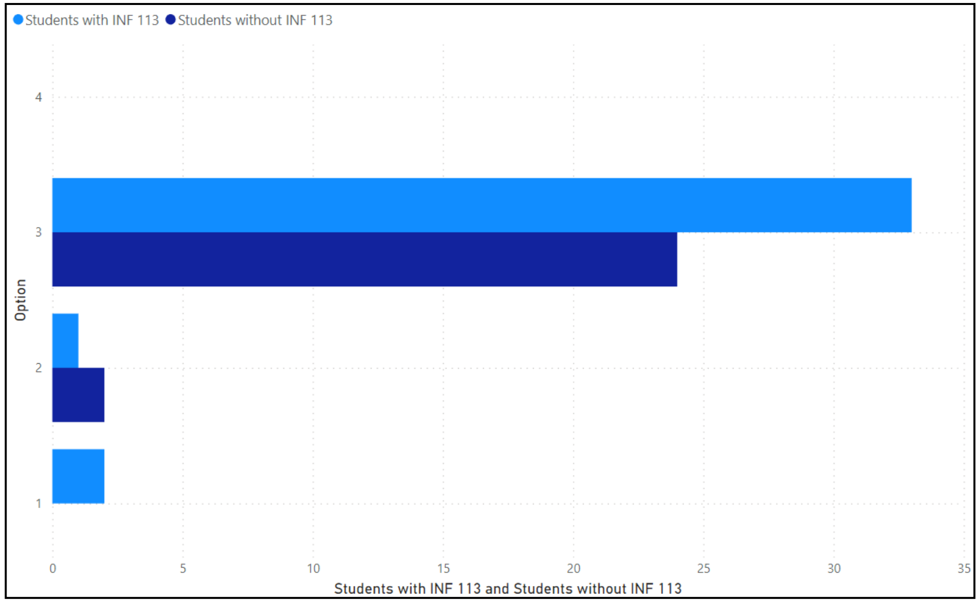
Question 10: What is algorithmic thinking?

The tenth question sought to identify whether respondents could demonstrate a basic understanding of algorithmic thinking by identifying the correct definition for algorithmic thinking.

Pre-Test



Post-Test



Pre-Test:

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Developing the necessary input to solve a	2	3	

Post-Test:

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Developing the necessary input to solve a	2	3	

problem			
2 = Developing the necessary processing to solve a problem	6	10	
3 = Developing the necessary step-by step solution to solve a problem	54	87	☑
4 = Developing the necessary output to solve a problem	-	-	

Based on the results above, 54 (87%) of the respondents identified the correct answer, while 8 (13%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	86	14
Respondents without INF 113	26	88	12

problem			
2 = Developing the necessary processing to solve a problem	3	5	
3 = Developing the necessary step-by step solution to solve a problem	57	92	☑
4 = Developing the necessary output to solve a problem	-	-	

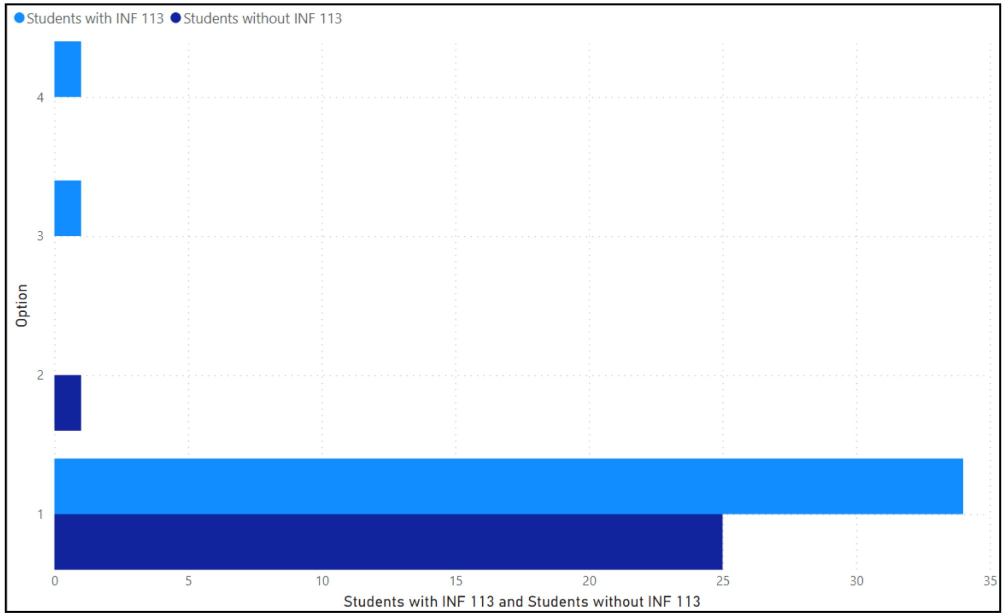
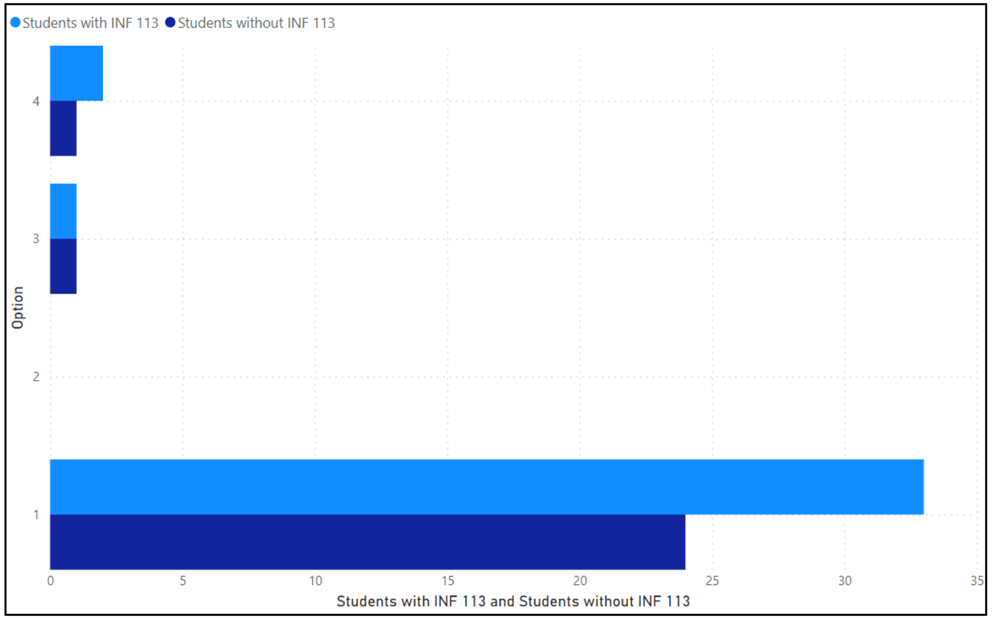
Based on the results above, 57 (92%) of the respondents identified the correct answer, while 5 (8%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	92	8
Respondents without INF 113	26	92	8

Table 37: What is algorithmic thinking? (Cycle 3)

Question 11: What is an example of algorithmic thinking?

The eleventh question sought to identify whether respondents could apply the definition of algorithmic thinking by identifying the correct example in which algorithmic thinking can be applied

Pre-Test	Post-Test
	

Pre-Test

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = An installation manual	59	95	☑
2 = A comic strip	1	1.6	

Post-Test

Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = An installation manual	57	92	☑
2 = A comic strip	-	-	

3 = A map	1	1.6	
4 = A list of items on sale	1	1.6	

Based on the results, 59 (95%) of the respondents identified the correct answer, while 3 (5%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	94	6
Respondents without INF 113	26	96	4

3 = A map	2	3	
4 = A list of items on sale	3	5	

Based on the results above, 57 (92%) of the respondents identified the correct answer, while 5 (8%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

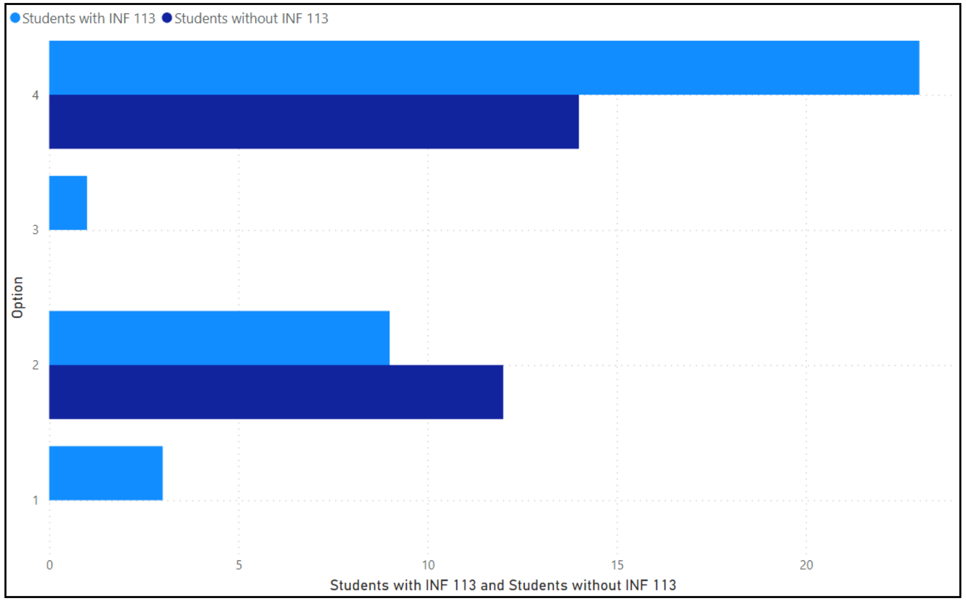
Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	92	8
Respondents without INF 113	26	92	8

Table 38: What is an example of algorithmic thinking? (Cycle 3)

Question 1.12: What is evaluation?

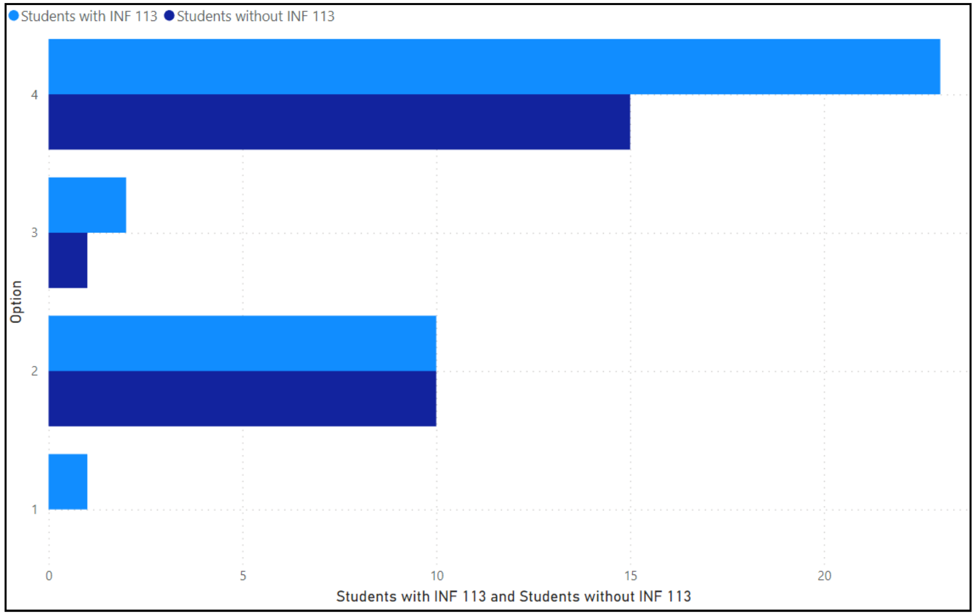
The eleventh question sought to identify whether respondents could apply the definition of algorithmic thinking by identifying the correct example in which algorithmic thinking can be used.

Pre-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Evaluating solutions for any similarities	3	5	
2 = Evaluating solutions against desired	21	34	

Post-Test



Variable	Frequency (n)	Percentage (%)	Correct Answer
1 = Evaluating solutions for any similarities	1	1	
2 = Evaluating solutions against desired	20	32	

outcomes			
3 = Evaluating certain parts of the solution	1	1.6	
4 = All of the above	37	60	☑

Based on the results above, 37 (60%) of the respondents identified the correct answer, while 25 (40%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	64	36
Respondents without INF 113	26	54	46

outcomes			
3 = Evaluating certain parts of the solution	3	5	
4 = All of the above	38	61	☑

Based on the results above, 38 (61%) of the respondents identified the correct answer, while 23 (39%) identified the incorrect answer. The results between the respondents with and without INF 113 were as follow:

Category	Frequency (n)	Percentage (%) that answered correctly	Percentage (%) that answered incorrectly
Respondents with INF 113	36	64	36
Respondents without INF 113	26	58	42

Table 39: What is evaluation? (Cycle 3)

4.4.2.2. Pre- and Post-Test Questionnaire Analysis

For the researcher to determine how each group performed during each test, an average was calculated per test (see Table 32 for more detail).

		Average (%)	
Group	**Number of Students**	**Pre-Test**	**Post-Test**
Respondents with INF 113	36	82	85
Respondents without INF 113	26	77	80

Table 40: Pre- and Post-Test Analysis (Cycle 3)

For the researcher to determine whether there was a significant difference between the averages calculated above, a t-test was conducted. The null hypothesis of the test stated that the difference between the means was because of chance; however, the results obtained from the t-test were as follow:

Students with INF 113

	Students with INF 113	Students without INF 113
Mean	0,824074074	0,851851852
Variance	0,024036663	0,019547325
Observations	12	12
Hypothesized Mean Difference	0	
df	22	
t Stat	-0,46091903	
P(T<=t) one-tail	0,324690415	
t Critical one-tail	1,717144374	
P(T<=t) two-tail	0,64938083	
t Critical two-tail	2,073873068	
Confidence Level	95	
Significance Level	0.05	

At a 0.05 percent level of significance and degree of freedom (df, 22), the p-value of 0,64938083 is more than the significance level of 0.05. Therefore, there is no significant difference between the means obtained from the two groups of students and, as a result, the researcher accepts the null hypothesis. The researcher confirms that the difference between the averages obtained from each group occurred by chance.

Students without INF 113

	Students with INF 113	Students without INF 113
Mean	0,769230769	0,804487179
Variance	0,036578806	0,028633226
Observations	12	12
Hypothesized Mean Difference	0	
df	22	
t Stat	-0,47826087	
P(T<=t) one-tail	0,318591451	
t Critical one-tail	1,717144374	
P(T<=t) two-tail	0,637182903	
t Critical two-tail	2,073873068	
Confidence Level	95	
Significance Level	0.05	

At a 0.05 percent level of significance and degree of freedom (df, 22), the p-value of 0,637182903 is more than the significance level of 0.05. Therefore, there is no significant difference between the means obtained from the two groups of students and, as a result, the researcher accepts the null hypothesis. The researcher confirms that the difference between the averages obtained from each group occurred by chance.

Table 41: Pre- and Post-Test T-Test (Cycle 3)

Although there was no significant difference between the averages, and the researcher concluded that the averages occurred by chance, both groups achieved a higher average in the post-test questionnaire compared to the pre-test questionnaire.

Upon completing the post-test questionnaire, the researcher distributed an evaluation form to determine how the respondents experienced the overall process. The evaluation form consisted out of the following three questions:

1. To what extent did the virtual escape room help you to understand computational thinking?
2. To what extent did the virtual escape room improve your attitude towards learning?
3. To what extent did computational thinking help you to understand the planning of a program better?

The responses to the questions were as follow:

Question 1: To what extend did the virtual escape room help you to understand computational thinking?

Scale	**Description**	**No of students**
1	To no extent	0
2	To little extent	3
3	To some extent	11
4	To large extent	26
5	To great extent	22

Table 42: Question 1 Evaluation Form

Most students indicated that the virtual escape room helped them to understand computational thinking, while the minority indicated that the virtual escape room only helped them to some extent.

Question 2: To what extend did the virtual escape room improved your attitude towards learning?

Scale	**Description**	**No of students**
1	To no extent	0
2	To little extent	1
3	To some extent	9
4	To large extent	28
5	To great extent	24

Table 43: Question 2 Evaluation Form

Most students indicated that the virtual escape room improved their attitude towards learning, while the minority indicated that the virtual escape room only improved their attitude to some extent.

Question 3 To what extend did computational thinking help you to understand the planning of a program better?

Scale	Description	No of students
1	To no extent	2
2	To little extent	3
3	To some extent	13
4	To large extent	16
5	To great extent	28

Table 44: Question 3 Evaluation Form

Most students indicated that computational thinking helped them to plan a program better, while the minority indicated that it only helped them to some extent.

Apart from the three questions above, a fourth question was also presented to the students in which they were allowed to provide any additional input on how they experienced the overall process. The feedback that was obtained was very positive. The main themes that emerged from these responses are that of enjoyment and fun, a good challenge and conducive for learning (see table 37 below):

Remark	Theme
"The escape room was pretty fun to do :-)"	Fun
"The escape room activity was interesting, but I do not think it aided to my understanding of computational thinking. It was just an interesting exercise that required a lot of thinking. I do believe I already understood what computational thinking was."	Good challenge, Conductive for learning
"This was a very fun exercise that helped solidify the abstract concepts"	Fun, Conductive for learning
"I really enjoyed this practical. It was very interesting and I learnt quite a bit."	Enjoyment, Conductive for learning
"The escape room was fun and interesting"	Fun, Enjoyment

"it was very productive to learn"	Conductive for learning
"I loved the interactive experience that the escape room provided! It was so much fun and really enabled me to put the theory behind computational thinking into practice. I would definitely participate in a similar event again."	Fun, Enjoyment, Conductive for Learning
"Great opening to Semester 2"	Fun
"I enjoyed the escape room, it was fun even though it was a bit challenging"	Fun, Good Challenge
"It was a really fun and creative way to go about teaching a concept which ordinarily is thought to be very linear."	Fun, Conductive for Learning
"The lesson was very informative"	Conductive for Learning
"I really enjoyed the exercise, I wish similar exercises can be made that are interesting like this one."	Enjoyment
"I enjoyed the escape room it was fun and challenging"	Enjoyment, Good challenge
"I loved the escape room even though I'd already learnt about computational thinking from INF113"	Enjoyment
"Enjoyed the escape room"	Enjoyment

Table 45: Evaluation Feedback (Cycle 3)

Based on the feedback received from the second cycle during the interviews and the results of the third cycle, the researcher revisited the second version of the VEscapeCT framework to make the following final adjustments:

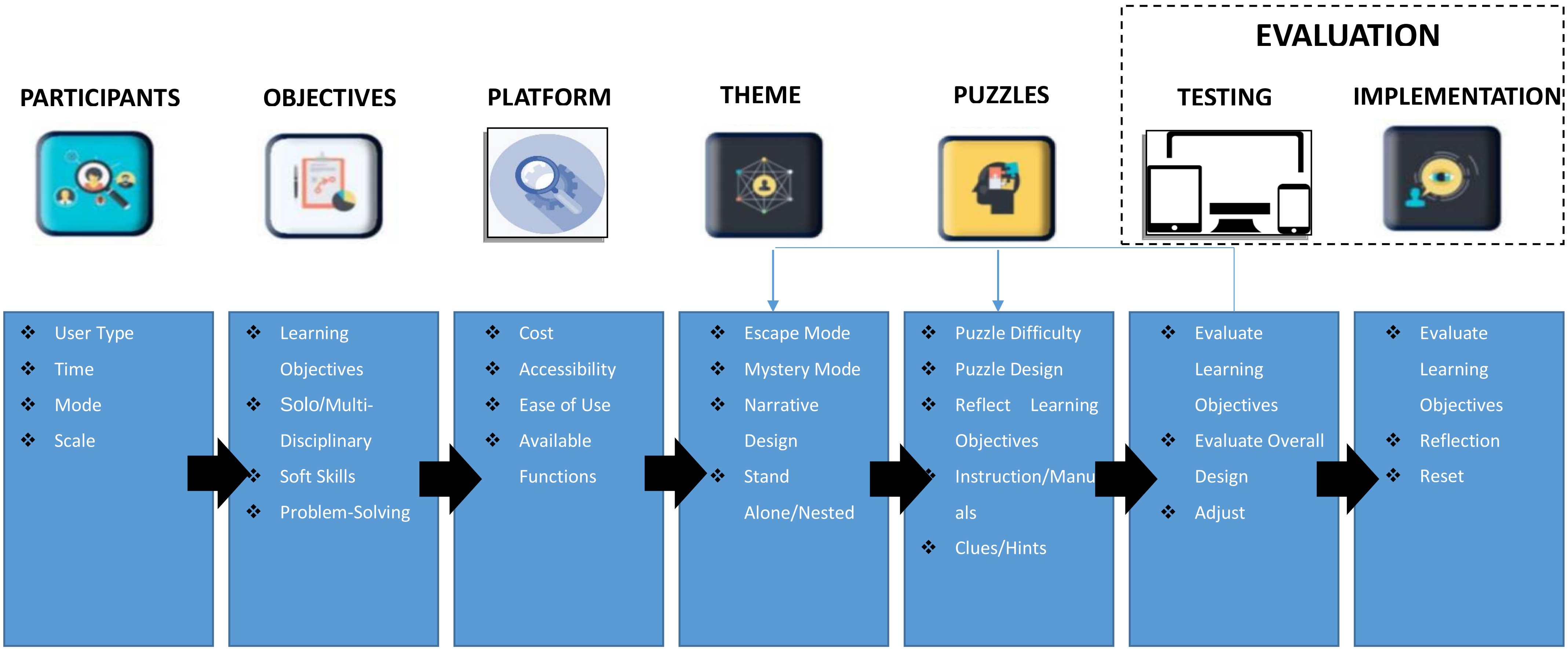


Figure 35: Final VEscapeCT Framework Version 3(Adapted from Clarke et al (2017)))

The following elements were adjusted or added

Participants (Adjusted)

Based on the feedback from the lecturers, the researcher decided to keep the User Type and User Requirements as one step.

Platform (Added)

The third component of the framework involves considering the platform on which the virtual escape room is going to be executed. It involves a complete analysis on the cost, availability, ease of use and available functions of the platform.

Cost

Is the platform open-source or will participants have to pay for the software to participate?

Accessibility

Will the platform be easily available for students, in other words, software they already have, or would they have to download additional software?

Ease of Use

Is the software easy to use for participants of would it require additional documentation/manuals etc.?

Available functions

Does the software provide all the necessary functions to execute the virtual escape room that you are planning?

The researcher also indicated that testing is crucial when it comes to virtual escape rooms, especially ones where there is no face-to-face contact involved with the students, because students should be able to complete the activity without any issues.

4.5 DISCUSSION

The primary purpose of the chapter was to determine whether the suggested framework could provide a way of using virtual escape rooms to facilitate computational thinking. Based on the analysis of the first cycle, the researcher could not determine whether the virtual escape room had any impact on the results of the questionnaires. The researcher then conducted a second cycle in which changes were made to the framework and presented to two senior lecturers from the Department of Informatics at the University of Pretoria. Both lectures provided feedback on where there was a potential for improvement; however, both agreed that an introductory lesson would be very beneficial before completing the virtual escape room. The data obtained from the interviews were analyzed during a third cycle. Based on the feedback, the researcher changed the framework and the virtual escape room and presented it again to another group of students. Since more students participated during the third cycle, the researcher was able to conduct a t-test. The results did not show any significant difference between the averages obtained from the questionnaires; however, much positive feedback was received from the students.

The researcher derived the following conclusions on why the results did not show any significant difference between the averages obtained from the questionnaires. Virtual escape rooms might not be enough on their own to facilitate computational thinking; instead, based on the feedback received in the study, a lesson is required at the start of the virtual escape room to provide students with a more detailed background on computational thinking. Based on the literature, studies have recommended that virtual escape rooms should be implemented together with formal lessons to create the ultimate learning experience for the students (Sánchez-Ruiz, et al., 2022; Cai, 2022; Torres, et al., 2022; Ang, et al., 2022; Anton-Solanas, et al., 2022). Furthermore, this study has shown that students enjoyed participating in the virtual escape room. Virtual escape rooms can, therefore, assist educators in getting students more involved with the learning experience since this study has shown how much students enjoyed the experience. Within various studies, motivation and enjoyment have also stood out as some of the key benefits. (Sánchez-Ruiz, et al., 2022; Cai, 2022; Torres, et al., 2022; Ang, et al., 2022; Anton-Solanas, et al., 2022). The researcher utilized a CT Diagnostic computational thinking assessment tool to create the questionnaires that were intended to measure the ability to create and solve problems in the virtual escape room by drawing on the basic concepts of computational thinking. According to Román-González, et al., (2017), if only one of the computational thinking assessment tools is utilized, it is very likely that an incomplete view of computational thinking is obtained. As such, the questionnaires might not have provided the complete view necessary for students to be able to solve the puzzles in the virtual escape room. Therefore, a combination of assessment tools is required to reach a complete and comprehensive understanding of computational thinking.

4.6 CONCLUSION

This chapter provided an analysis of the data obtained during each cycle based on the methodology provided in the previous chapter. It is divided into three sections, each representing one of the abovementioned cycles. The first section analyzed the data from the students that attended the INF 154 winter school; the second section analyzed the feedback received from the interviews with two lecturers at the university, and the third section analyzed the data from the students that attended the INF 164 lecture session. The chapter concludes by discussing why the overall results did not differ significantly.

5 DISCUSSION

5.1.1 Introduction

The following chapter is the concluding chapter of this research study. In this chapter, the researcher will answer the research questions, evaluate the research, contribute to the field of study, identify any limitations, and provide guidance for future research.

5.1.2 Research Questions

The main aim of the research study was to answer the following research questions:

Main Research Question:

What are the components of a framework guiding the use of virtual escape rooms in the teaching of computational thinking?

Sub- Research Question:

1. What are the benefits of virtual escape rooms used in education?
2. How are virtual escape rooms used in education?
3. How can the use of virtual escape rooms develop computational thinking skills?

The sub-questions will be answered first after which the main research question will be addressed.

What are the benefits of virtual escape rooms used in education?

The benefits that virtual escape rooms have to offer are manifold. Studies have reported that teaching through virtual escape rooms has the potential to provide conditions for deep learning, collaborative problem-solving, and active engagement. Other studies have indicated that virtual escape rooms promote skills such as working under pressure and communication (Makri, et al., 2021).

There were two benefits that have stood out in almost all the studies: motivation and enjoyment. All the studies agree that virtual escape rooms improve students' motivation and provide an enjoyable learning environment (Sánchez-Ruiz, et al., 2022; Cai, 2022; Torres, et al., 2022; Ang, et al., 2022; Anton-Solanas, et al., 2022). Based on the findings from the previous chapter, it is clear that although the results did not indicate a significant difference, virtual escape rooms can still be used by educators to motivate students or to get students more interested in a particular subject. However, if educators wish to create the ultimate learning experience, researchers recommend that virtual escape rooms be implemented with formal lessons due to the benefits they offer. Together this can provide students with not only the necessary motivation but also a comprehensive understanding of the particular subject (Sánchez-Ruiz, et al., 2022).

How are virtual escape rooms used in education?

Virtual escape rooms have been implemented through a variety of learning methods. Studies have reported on game-based learning where virtual escape rooms have been implemented through software such as the RPG Maker that allows for the development of role-playing video games (Sánchez-Ruiz, et al., 2022). Other studies have reported on problem-based learning where students had to work in groups to solve puzzles through Google slides (Cai, 2022; Torres, et al., 2022).

How can the use of virtual escape rooms develop computational thinking skills?

Studies have reported that escape rooms are a very suitable method to teach computational thinking because both immerse students in problem-solving scenarios. As with any competency, computational thinking can also be effectively learned when learners practice the knowledge they gain (Menon, et al., 2019). In escape rooms, learners have to apply the knowledge they gained to complete the challenges or tasks, thereby learning by doing. Six games were identified that currently exist with an escape theme: RaBit EscAPE, Pandemic, T-Maze, Program your Robot, CTArcade, and Toque (Berland & Lee, 2011; Wang, et al., 2014; Kazimoglu, et al., 2012; Lee, et al., 2011) . Of the six games, three were categorized as unplugged games, and three computer programming (Menon, et al., 2019). A further analysis was done to determine how many of these games met the criteria of an escape room game as defined by Nicholson (2015). Based on the results, only the three unplugged games met six or more characteristics (Menon, et al., 2019). Very little research has been done surrounding virtual escape rooms and how they can be used to facilitate computation thinking.

The above mentioned allowed the researcher to answer the main research question of the study:

What are the components of a framework guiding the use of virtual escape rooms in the teaching of computational thinking?

The framework consists of seven components: participants, objectives, platform, theme, puzzles, testing and evaluation. Each of these components will be discussed in more detail below:

Participants:

The first component involves developers carrying out a user assessment, which includes details such as the target audience. Conducting an analysis of the target audience early on in the process is considered conventional practice in most disciplines and common for entertainment game companies.

Objectives:

The second component involves developing the learning objectives for the virtual escape room experience. According to Arnab & Clarke (2016), developing the learning objectives early on in the game ensures that the experience is designed purposefully and that the game theme and puzzles can be developed to enhance the objectives rather than to embed the objectives into an already designed game.

Platform

The third component involves assessing the available platforms that can be used to implement virtual escape rooms. Conducting an analysis early on in the game allows the developer to select a platform that is not expensive, easy to access, easy to use, and contains the necessary functions that would allow the developer to set up the puzzles as planned. The researcher moved this component before the puzzles component because when the researcher created the virtual escape room, the researcher first started with the puzzles component and then moved on to the platform component, only to realize that the selected platform did not support the puzzles that were planned because of limited functionality. The researcher then decided that the platform should be selected first so the developer knows what is possible when it comes to creating the puzzles.

Theme

The fourth component is for developers to consider the overall theme of the experience. This step involves considering the player motivations, game story and content to bring a compelling game experience for the players.

Puzzles

The fifth component involves developing puzzles and activities that the players will interact with during the game. The puzzles are designed by using the information obtained in the previous steps.

Evaluation

The researcher decided to split the evaluation component into two sub components: Testing and Implementation. The researcher found testing an essential component because students completed the virtual escape room online, so the researcher had to ensure that everything was working and that everything made sense since there was no physical class. The implementation component involves implementing the virtual escape room with the group of students.

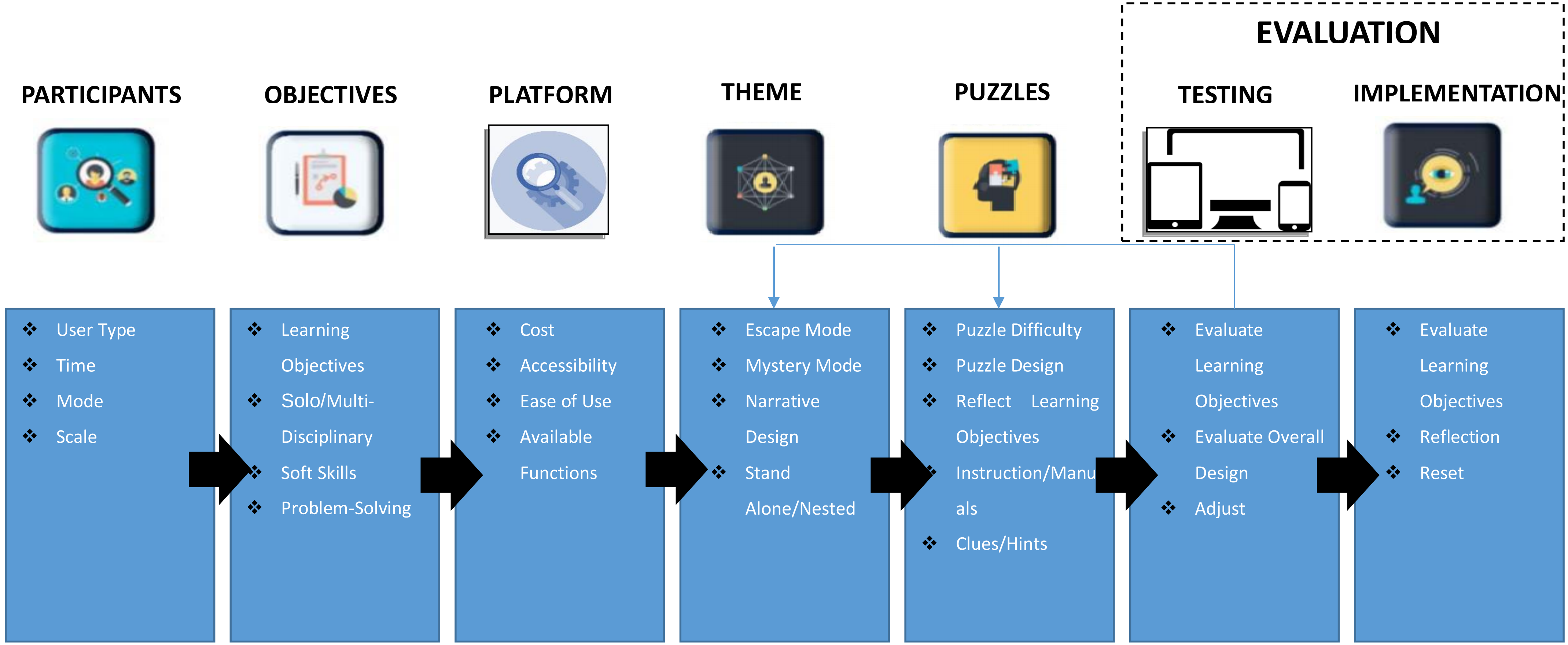


Figure 36: Final VEscapeCT Framework Version 3(Adapted from Clarke et al (2017)))

5.1.3 Evaluate Research

The following criteria was used by the researcher to judge the accuracy of the research: dependability, credibility, confirmability, and transferability.

Dependaility: Research can be viewed as dependable if two researchers assessing the same phenomenon arrive at the same conclusions using the same evidence (Bhattacherjee, 2012). The literature and the researcher have concluded that virtual escape rooms are an excellent tool for motivating learners. Apart from that, the literature and the researcher have also concluded that the virtual escape room is insufficient to provide a comprehensive understanding of computational thinking. Instead, a formal lesson is required together with the virtual escape room.

Credibility: Research can be considered credible if readers find its conclusion to be believable (Bhattacherjee, 2012). The researcher conducted three cycles to test whether the suggested framework could provide a way of using virtual escape rooms to facilitate computational thinking.

Confirmability: Refers to the extent to which others can confirm the findings (Bhattacherjee, 2012). The findings from the study are based on the data and feedback obtained during each of the three cycles and not the researcher's opinions. The three cycles can provide an audit trail to other parties interested in this research study showing how each conclusion was derived.

Transferability: Refers to the extent to which the findings can be generalized to other settings (Bhattacherjee, 2012). Although the main objective of the research was to develop a framework to create a virtual escape room for computational thinking, the framework was not only aimed at computational thinking. Educators and researchers can implement the framework in any field for any subject.

5.1.4 Contribution

The intended end result of this research study is to suggest a framework that could provide a way of using virtual escape rooms to facilitate computational thinking. There are thus two contributions: theoretical and practical.

5.1.4.1. Practical Contribution

The practical contribution that the research brought is the virtual escape room which is presented in Chapter 4. Although the virtual escape room was set up around a specific theme, it can still be used by any educator and researcher as a guide on incorporating the different components of computational thinking into themes and puzzles.

5.1.4.2. Theoretical Contribution

There are two theoretical contributions that the research brought:

- Although the research results proved insignificant, the literature suggests the ADAPTTER framework to incorporate computational thinking into the curriculum. The framework consists of 8 phases: activities, demonstration, application, pre-activation, theory, transparency, exemplification, and reflection (Kirwan, et al., 2022). The framework can be used to design a high-quality, engaging, practical, effective, and low-threshold computational thinking course. The researcher suggests that virtual escape rooms can be implemented during the pre-activation phase, where students must apply existing knowledge. This supports both the literature and feedback received regarding the virtual escape that should be implemented with formal lessons to create the ultimate learning experience (Sánchez-Ruiz, et al., 2022).
- The second theoretical contribution is the VEscapeCT framework provided in the section above.

5.1.5 Limitations

The researcher identified the following limitations in the study:

- The study only considered first-year students who studied IT-related degrees at the University of Pretoria.
- Due to COVID-19 restrictions, the researcher could not monitor the students as they participated in the escape room.
- The researcher cannot say that the students completed the activities in the order given.

5.1.6 Future Research

The researcher identified the following opportunities for future research:

- The researcher did not conduct a fourth cycle to test the final framework. There is, therefore, an opportunity to implement the framework to determine whether it could provide a virtual escape room to facilitate computational thinking skills.
- The researcher previously suggested that the virtual escape room can be implemented within the ADAPTTER framework. There is an opportunity to determine whether this is possible and what the outcome would be.

5.1.7 Contribution

This chapter attempted to answer the research questions, evaluate the research to judge the accuracy of the research, contribute to the field of study based on the research findings, and provide guidance for future research opportunities that may result from the research study.

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APPENDIX A

Virtual Escape Room Version 1

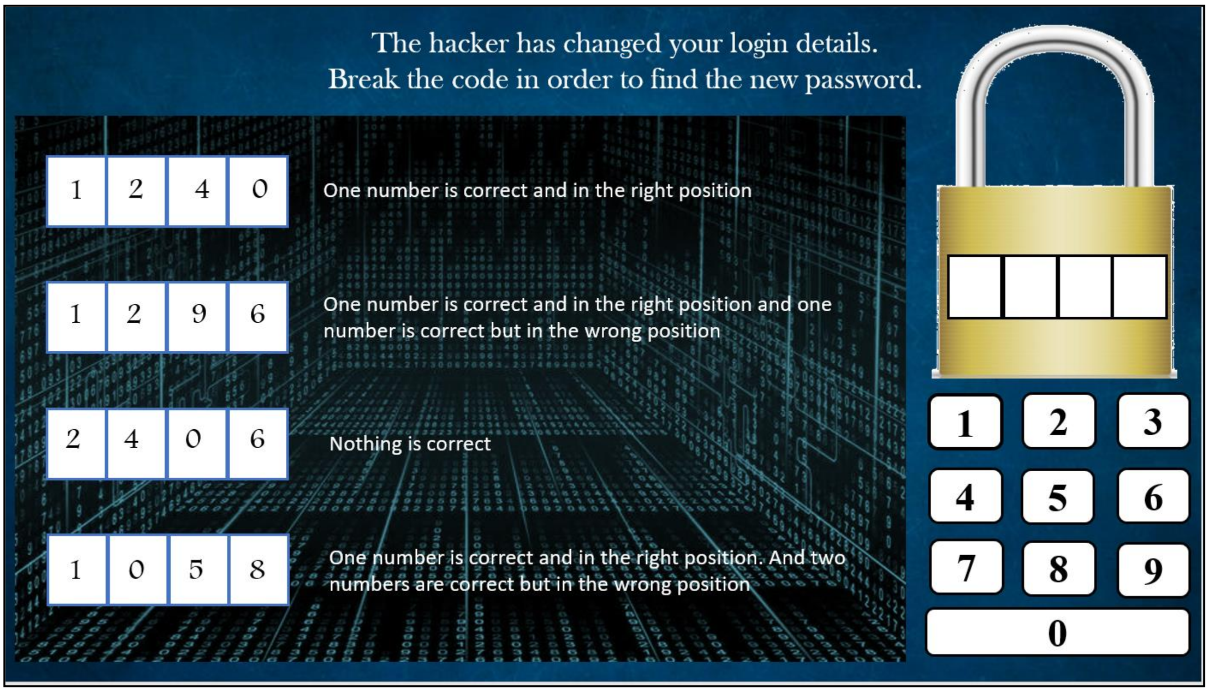

Figure 37: Virtual Escape Room Puzzle 1

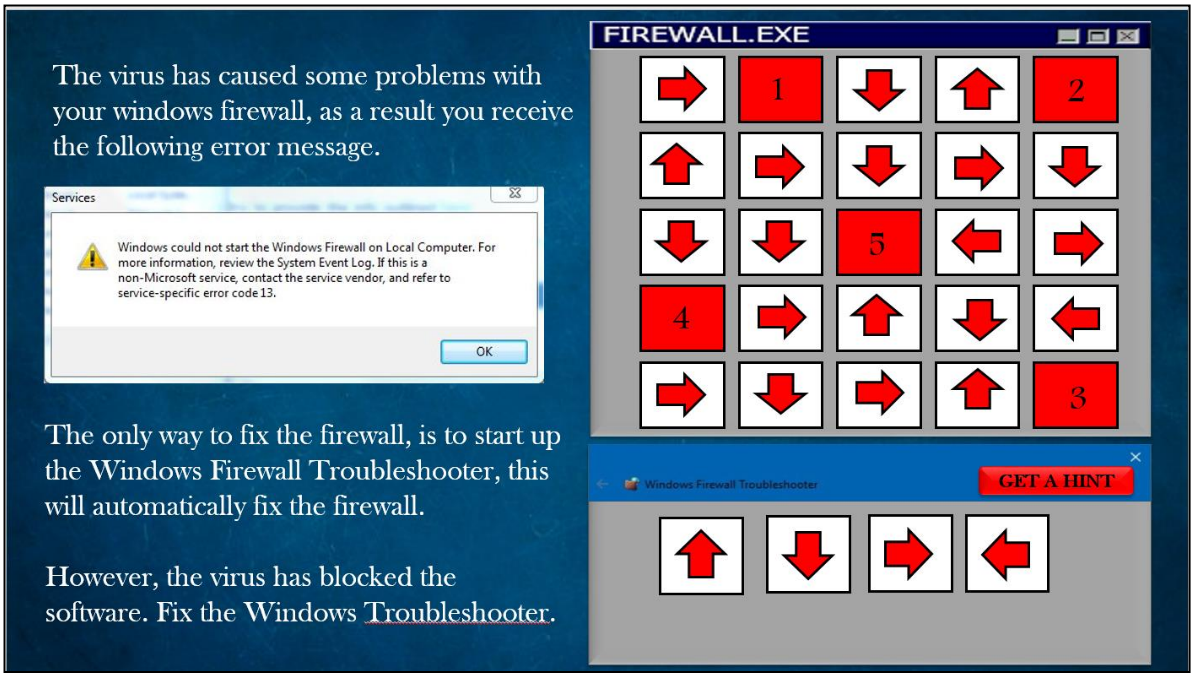

Figure 38: Virtual Escape Room Puzzle 2

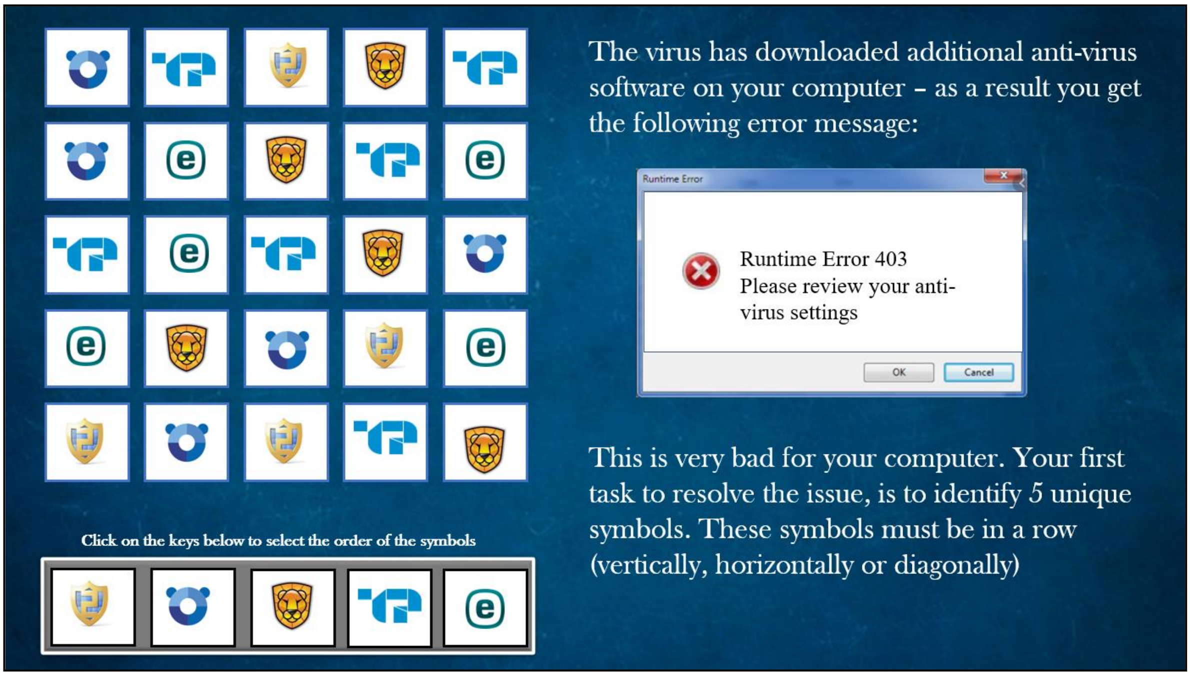

Figure 39: Virtual Escape Room Puzzle 3

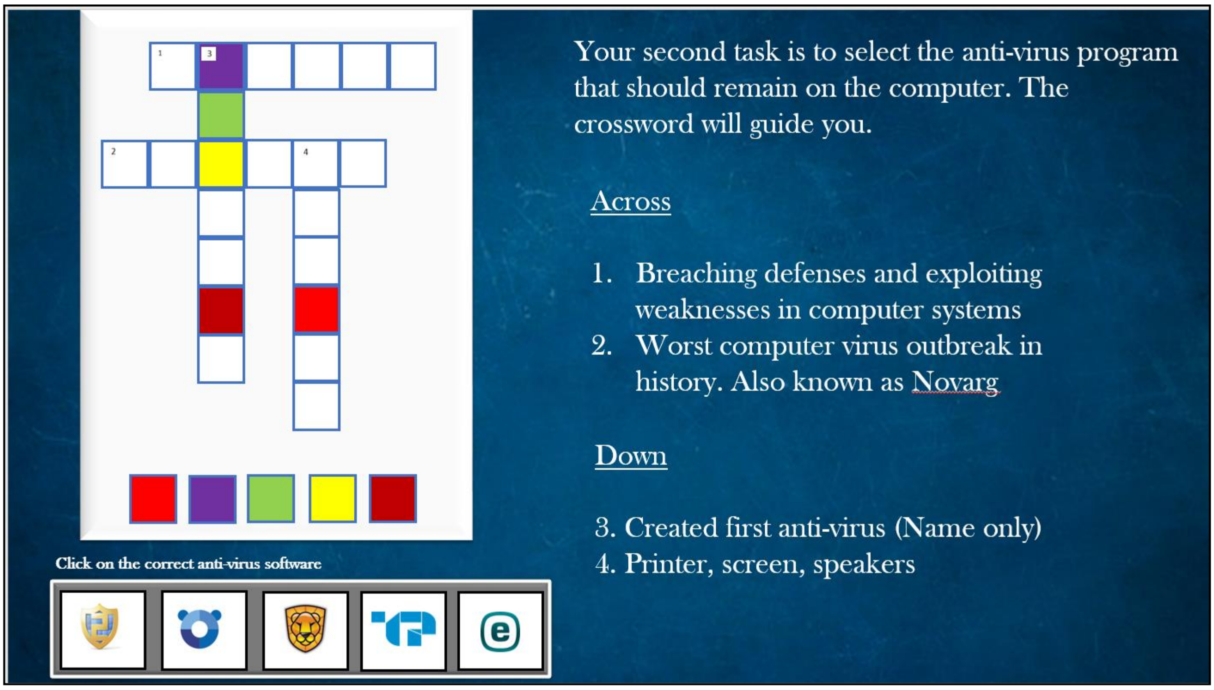

Figure 40: Virtual Escape Room Puzzle 4

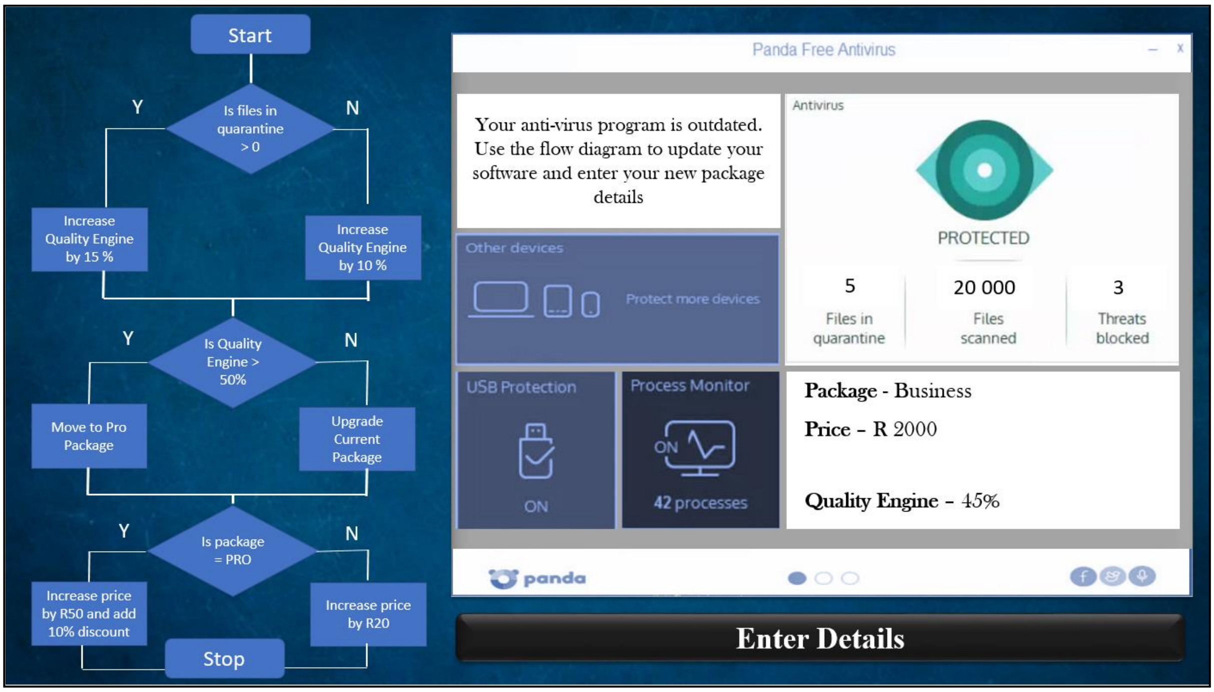

Figure 41: Virtual Escape Room Puzzle 5

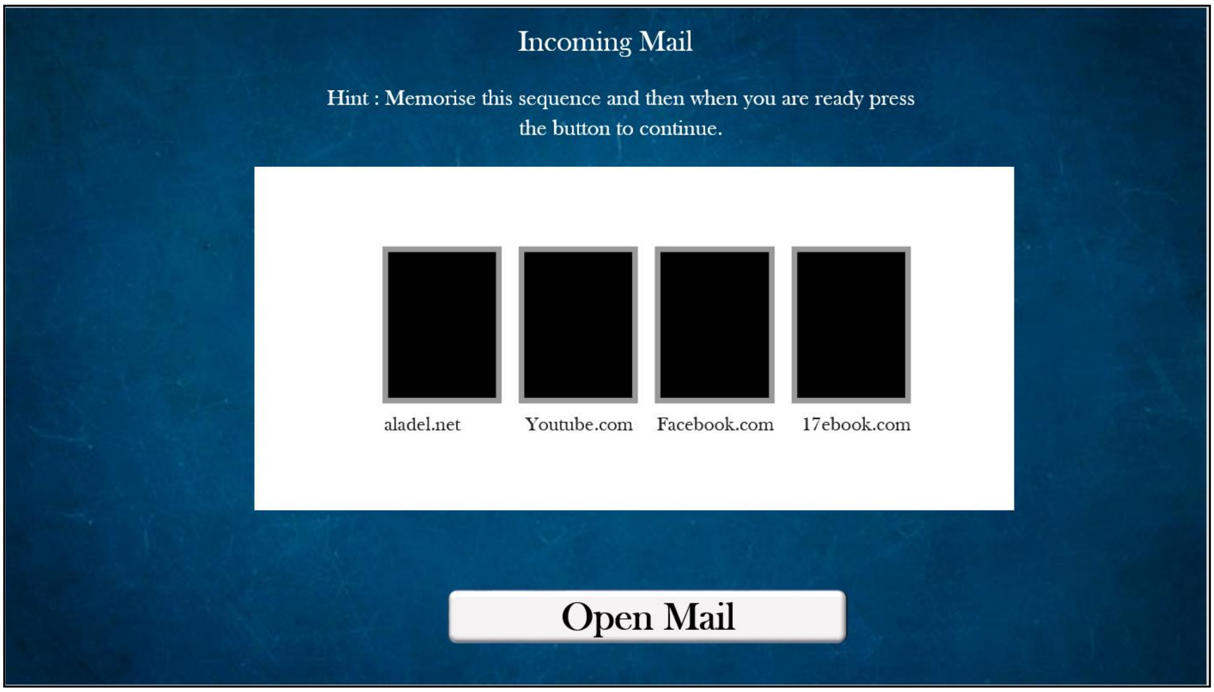

Figure 42: Virtual Escape Room Puzzle 6

APPENDIX B

Virtual Escape Room Version 2

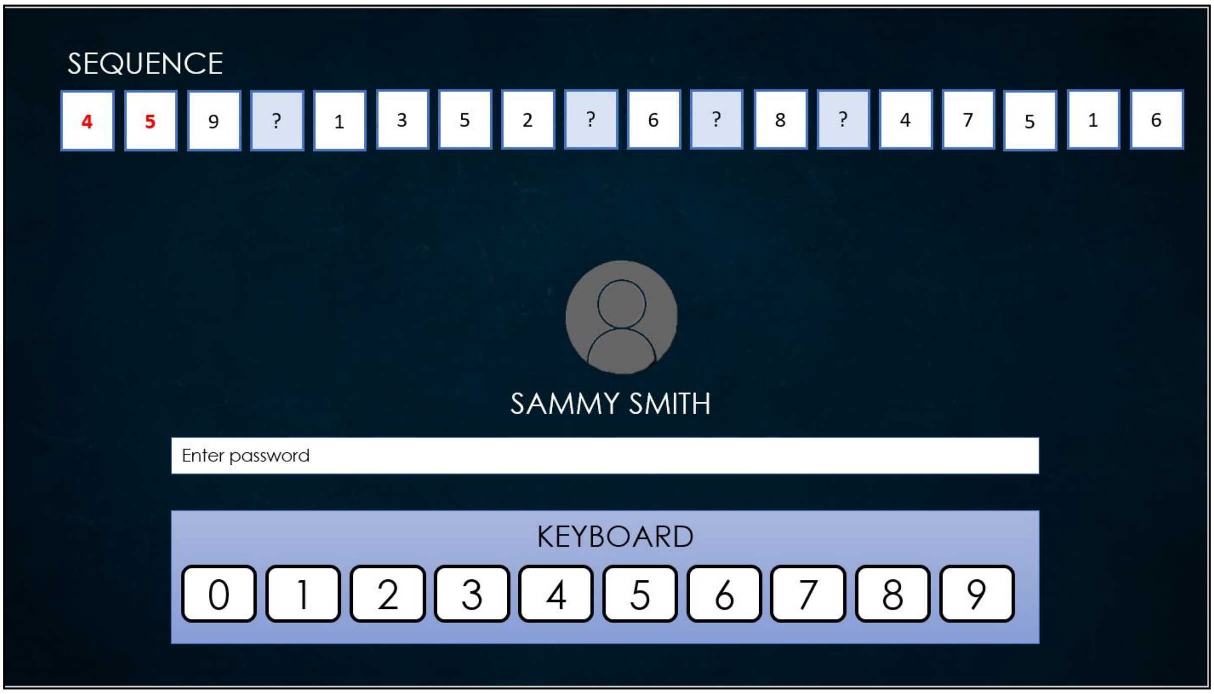

Figure 43: Virtual Escape V2 Room Puzzle 1

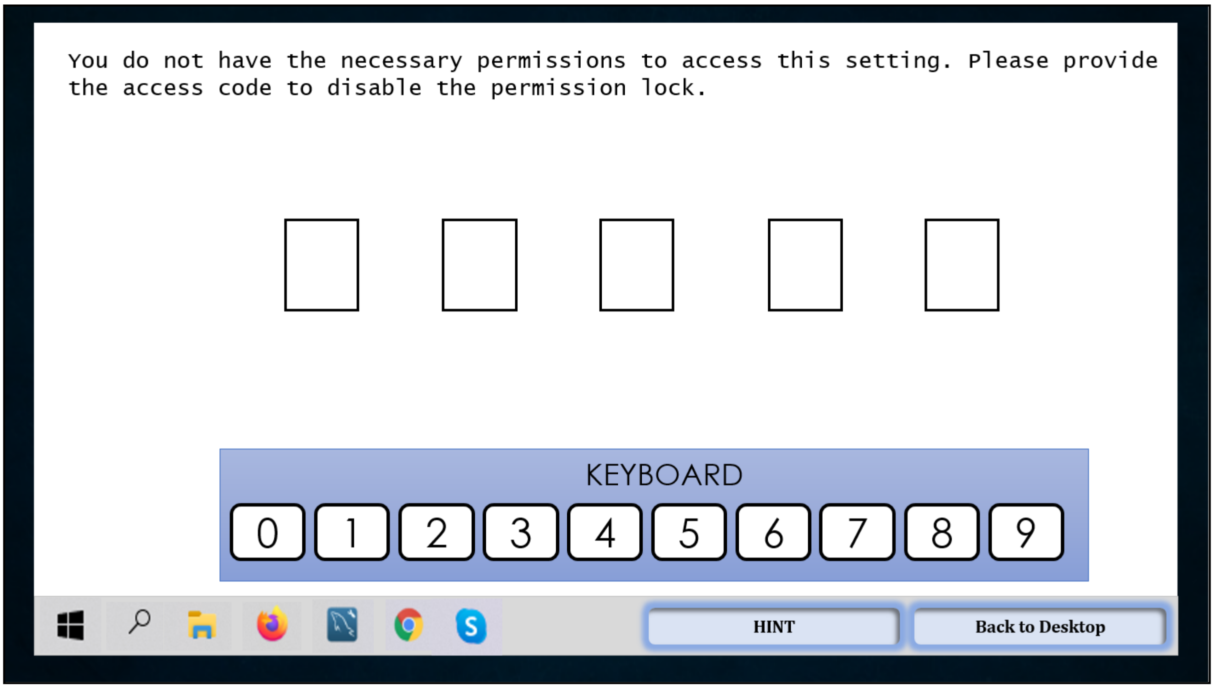

Figure 44: Virtual Escape V2 Room Puzzle 2

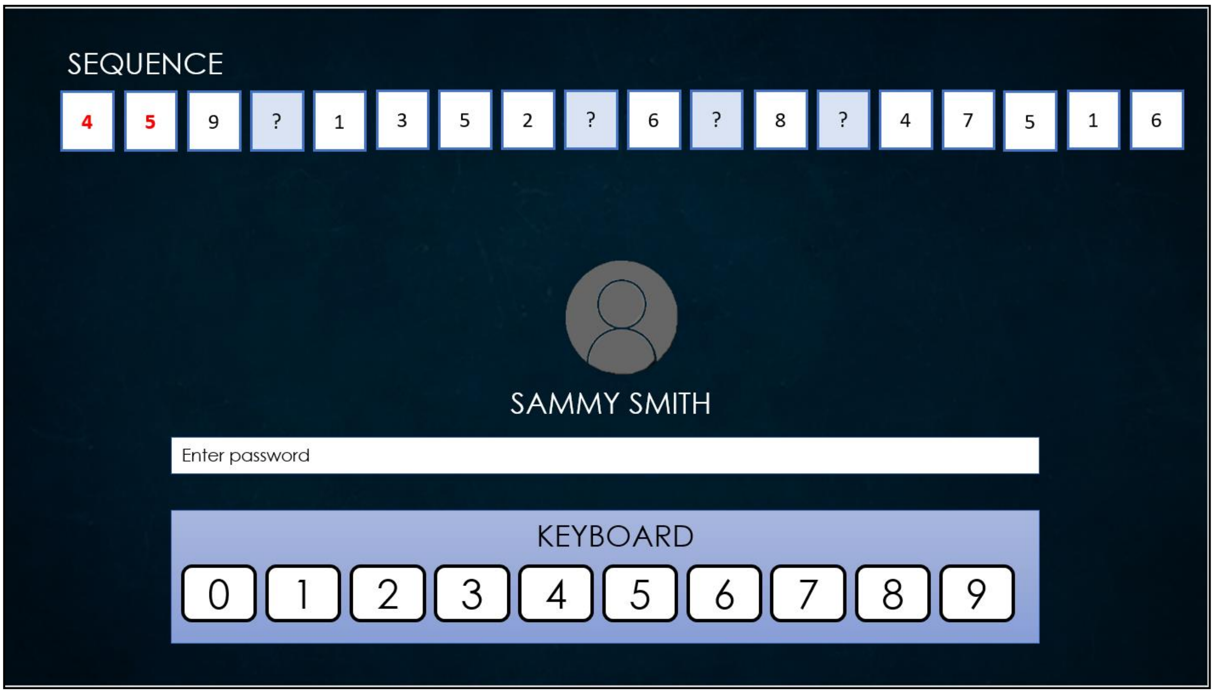

Figure 45: Virtual Escape V2 Room Puzzle 1

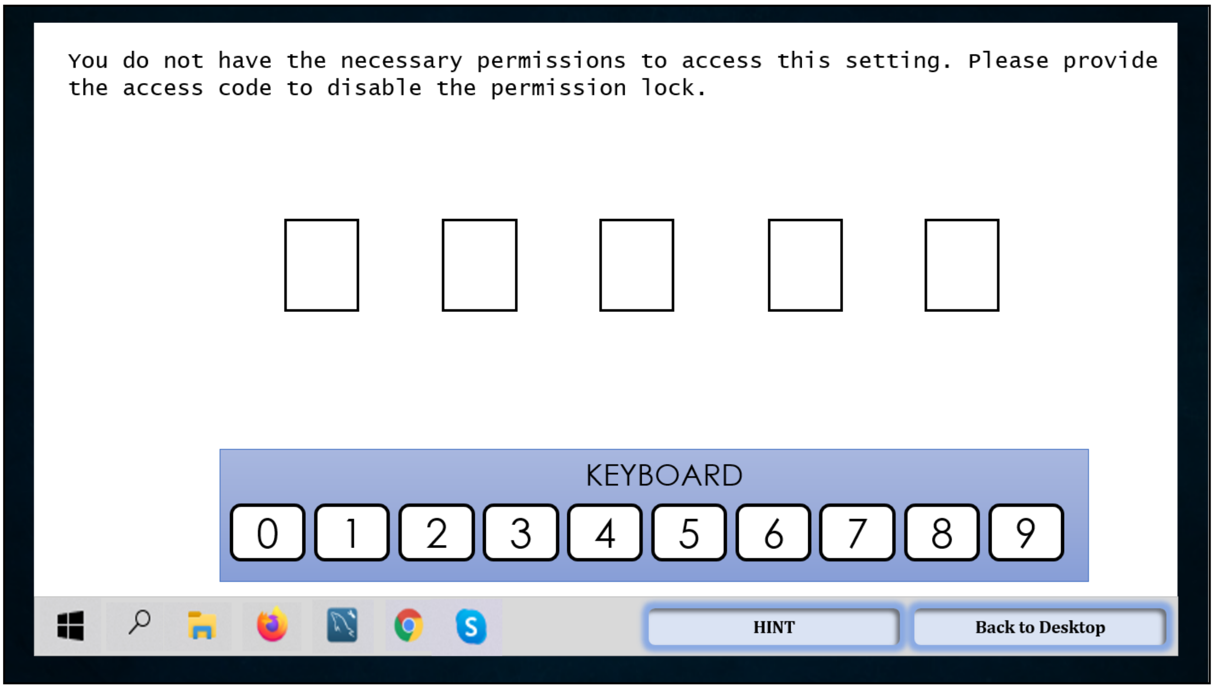

Figure 46: Virtual Escape V2 Room Puzzle 2

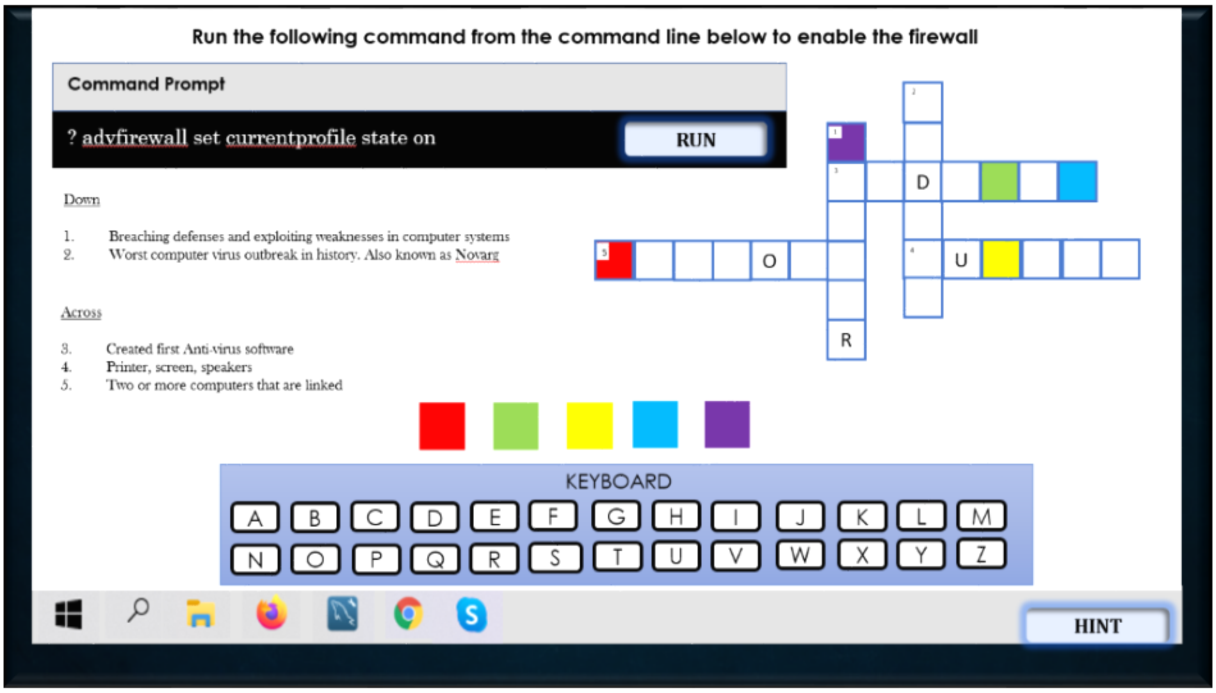

Figure 47: Virtual Escape V2 Room Puzzle 3

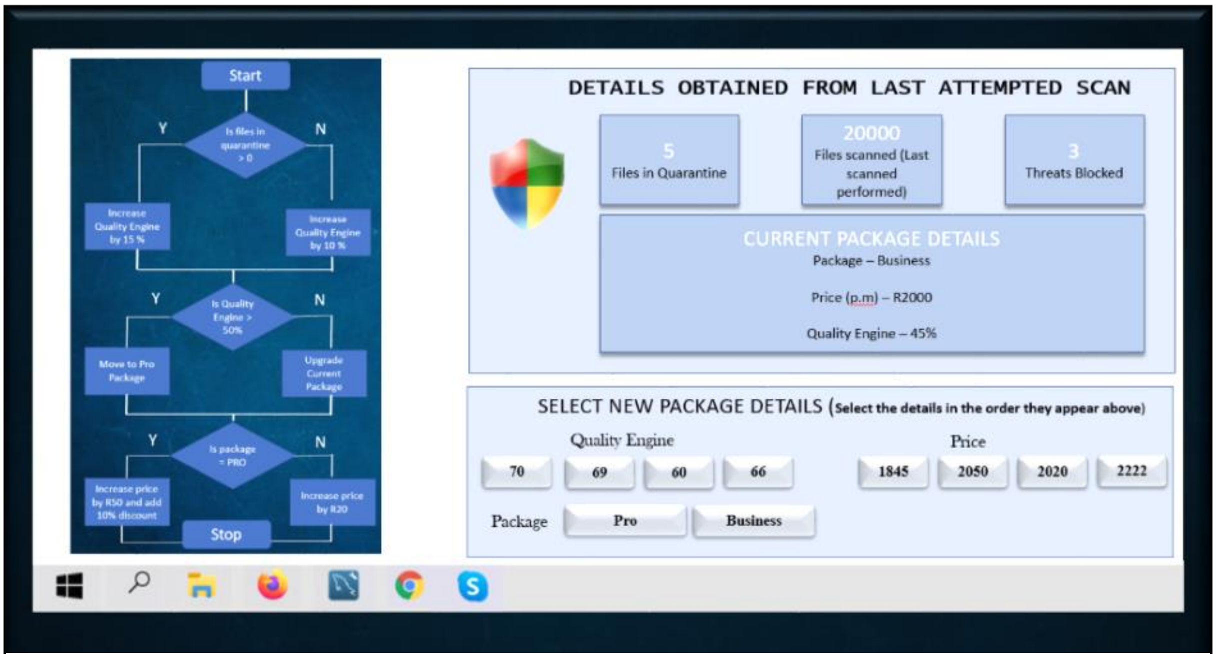

Figure 48: Virtual Escape V2 Room Puzzle 4

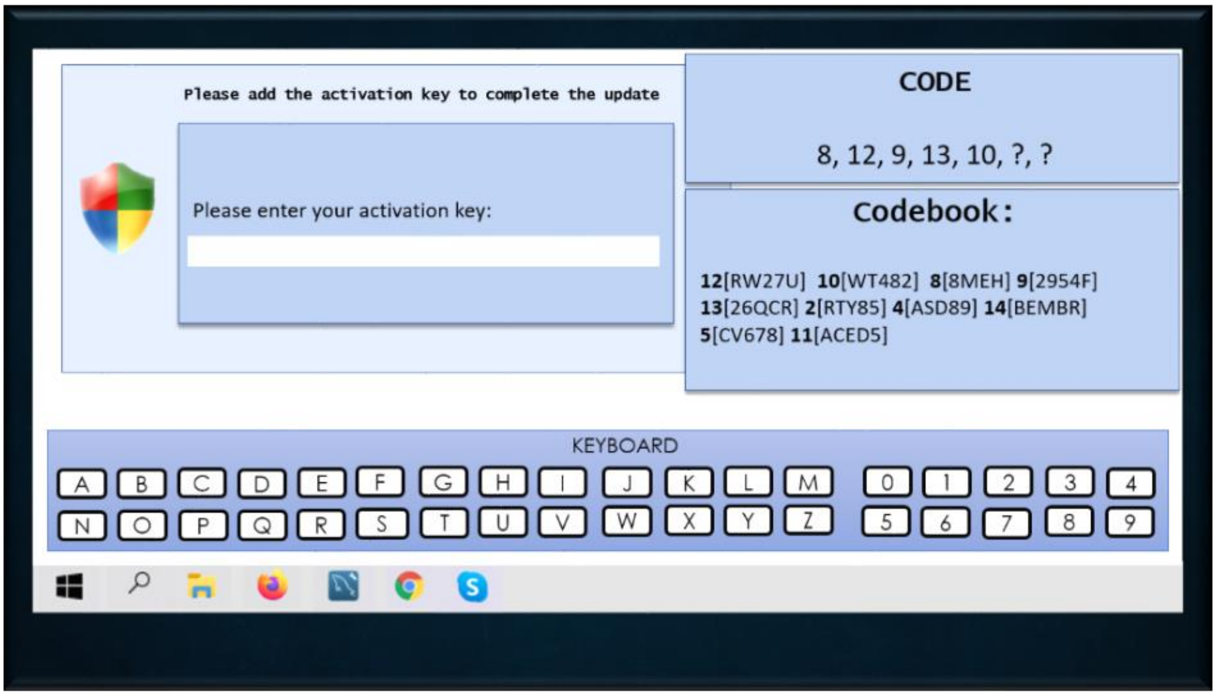

Figure 49: Virtual Escape V2 Room Puzzle 5

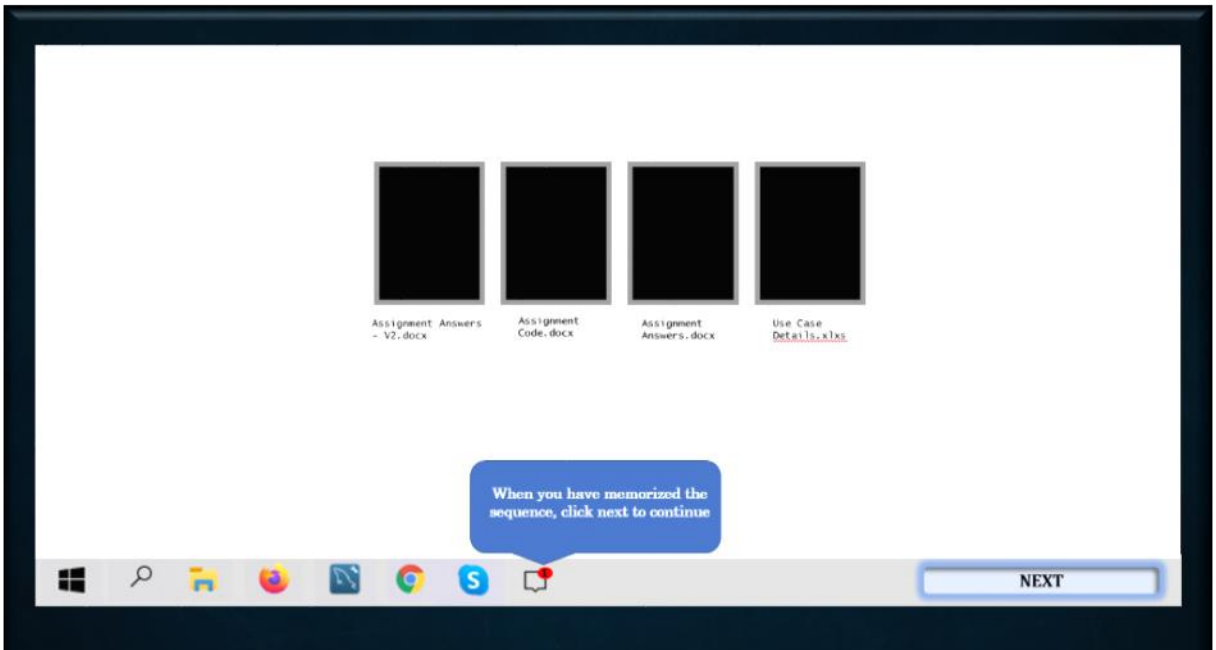

Figure 50: Virtual Escape V2 Room Puzzle 6

APPENDIX C

Computational Thinking Pre-and Post-Test

Computational Thinking Test

Section A: Identify the correct statement in each of the following questions

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1. What is computational thinking?

a) The way computers think

b) A problem-solving approach that **only** computer scientists use, that involves expressing problems in a way that computers can understand

c) A problem-solving approach that can be used by anyone, that involves expressing problems in a way that computers can understand

d) The way computers follow instructions

2. Which of the following is an example of computational thinking?

a) Sorting important documents

b) Choosing a line at the supermarket

c) Running Errands

d) All of the above

3. In which of the following disciplines can computational thinking be applied?

a) English Literature

b) Mathematics

c) Computer Science

d) All of the above

4. What is decomposition?

a) Breaking a big problem into smaller problems that are easier to solve

b) Removing necessary details in a problem

c) Breaking a big problem into smaller problems that challenges our way of thinking

d) Removing unnecessary details in a problem

5. What is an example of decomposition?

a) Baking a cake

b) Looking at what different kinds of cake can be made

c) Thinking about how we can make it the best cake

d) When baking a cake, thinking about what ingredients to get together, what the method is and how the cake should be decorate

6. What is pattern recognition?

a) Removing necessary details from a problem
b) Identifying differences in problems
c) Removing unnecessary details from a problem
d) Identifying similarities in problems

7. What is an example of pattern recognition?

a) Uploading a photo to Facebook
b) Facebook's Location Services
c) Facebook's Facial Recognition
d) Uploading a photo to Instagram

8. What is abstraction?

a) Drawing conclusions from problems by applying abstract thinking
b) Simplifying a problem by only dealing with the important details and neglecting the unnecessary details
c) Simplifying a problem by only dealing with the unimportant details and neglecting the necessary details
d) Drawing important details from problems by applying abstract thinking

9. What is an example of abstraction?

a) A map
b) A house plan
c) A sign of an aisle in a store
d) All of the above

10. What is algorithmic design

a) Developing the necessary input to solve a problem
b) Developing the necessary processing to solve a problem

c) Developing the necessary step-by step solution to solve a problem
d) Developing the necessary output to solve a problem

11. What is an example of algorithmic design?

a) An installation manual
b) A comic strip
c) A map
d) A list of items on sale

12. What is Evaluation?

a) Evaluating solutions for any similarities
b) Evaluating solutions against desired outcomes
c) Evaluating certain parts of the solution
d) All of the above

APPENDIX D

Ethical Clearance Approval

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

RESEARCH ETHICS COMMITTEE

Faculty of Economic and Management Sciences

AMENDMENT APPROVAL CERTIFICATE

21 May 2020

Miss T Janse van Rensburg
Department: EMS Deans Office

Dear Miss T Janse van Rensburg

The amendments to the research project described below served before this committee on:

Protocol No:	EMS207/19
Principal researcher:	Miss T Janse van Rensburg
Research title:	A framework for creating educational escape rooms to teach computational thinking
Student/Staff No:	15237185
Degree:	Masters
Supervisor/Promoter:	Prof MC Matthee
Department:	EMS Deans Office

The decision by the committee is reflected below:

Decision:	Approved
Conditions (if applicable):	Dean's permission required for using students as participants.
Period of approval:	2019-12-06 - 2020-11-30

We wish you success with the project.

Sincerely

PP PROF JA NEL CHAIR:

COMMITTEE FOR RESEARCH ETHICS

Fakulteit Ekonomiese en Bestuurswetenskappe
Lefapha la Disaense tša Ekonomi le Taolo

APPENDIX E

Interview Transcripts

Interview Transcript – Lecturer 1

Question 1:
Looking at the questions set out in the pre-and post-test, would you agree that the questions are sufficient to access a student's computational thinking skills? Please motivate your answer.

"Yes, in my opinion, the questions are sufficient because, as an educator, the objective of any assessment is to encourage higher-order thought in the students, which is what you have achieved. You are starting at the lowest level, where you ask students to define each concept, and from there, you are building on that knowledge by asking them to apply what they have learned within the definition."

Question 2:
By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of decomposition?

"No, I can't entirely agree. The puzzle, in my opinion, illustrates more abstraction than decomposition because students have to focus on one row of numbers at a time to figure out what the final code is. They therefore only focus on that particular row, ignoring the other rows that are not important."

Question 3:
By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of pattern recognition?

"Yes, I agree. The puzzle clearly illustrates the concept of pattern recognition because students have to complete the pattern on the screen by replacing the number on the diagram with the arrow that fits in the pattern."

Question 4:
By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of abstraction?

"Yes, I agree with the component illustrated in this puzzle because students have to go through each row of symbols to find the row containing the five unique symbols. As they do that, they only focus on that particular, thus ignoring the other rows that are not important."

Question 5:

By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of decomposition?

"This puzzle illustrates the concept of decomposition a bit better than the first challenge because the puzzle requires the student to (1) solve the crossword puzzle and (2) select the appropriate antivirus icon based on the answers in the crossword puzzle. Therefore, the student would have to divide this puzzle into smaller, more manageable steps to solve it. However, I feel abstraction is involved as well. When the students search for the crossword answers, they only focus on the information necessary to solve the crossword puzzle and not all the information presented. This puzzle illustrates the concept of decomposition a bit better than the first challenge because the puzzle requires the student to (1) solve the crossword puzzle and (2) select the appropriate antivirus icon based on the answers in the crossword puzzle. Therefore, the student would have to divide this puzzle into smaller, more manageable steps to solve it. However, I feel abstraction is involved as well. When the students search for the crossword answers, they only focus on the information necessary to solve the crossword puzzle and not all the information presented."

Question 6:

By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of algorithmic thinking?

"Yes, I agree. The puzzle clearly illustrates the concept of algorithmic thinking because students have to follow the algorithm on the screen to obtain the details necessary to update the anti-virus software."

Question 7:

By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of pattern recognition?

"Yes, I agree. The puzzle clearly illustrates the concept of pattern recognition because students have to follow the pattern of the flashing lights to determine what "mail" to open and which to avoid."

Question 8:
In your opinion, what additional support (if any) is required to assist students in completing the computational thinking assessments apart from the virtual escape room?

"The virtual escape room is a great tool to teach students about computational thinking because it can encourage learning and excitement. My only suggestion would be, especially for someone who has never heard about computational thinking, to implement a small introductory lesson at the start to provide them with a high-level overview of what computational thinking entails."

Question 9:
By examining the suggested VEscapeCT framework below, do you agree with the adjustments made to the framework compared to the original framework shown at the beginning of this interview?

"I would have to disagree regarding the first adjustment you illustrated to me, splitting the User Type into User Type and User Requirements. I think it can remain as one step in which you have to do proper research on what type of participants you will deal with and what requirements they would need to complete the virtual escape room.

Regarding the second adjustment that you illustrated to me, moving the Difficulty from the Participants section to the Puzzle section, I agree with you because you can't determine the difficulty levels of the puzzles before the design of the puzzles. You can maybe determine upfront that the puzzles shouldn't be too difficult, but on the other hand, you also want to add that various difficulty levels to make the experience a challenge."

Question 10:

In your opinion, what other adjustments would you recommend for the VEscapeCT framework to further adjust it to the needs of a virtual escape room?

"I suggest removing the Location and Actors steps under the Virtual Equipment section because they won't be required for a virtual escape room. Instead replace the Actors with Virtual Actors and the Location with Platform."

Interview Transcript – Lecturer 2

Question 1:

Looking at the questions set out in the pre-and post-test, would you agree that the questions are sufficient to access a student's computational thinking skills? Please motivate your answer.

"Yes, I agree that the questions in both the pre-and post-test are sufficient to test a student's knowledge on computational thinking because you provide them with different levels of questions: (1) test whether they can define each concept, and (2) test whether they can apply that knowledge in an example"

Question 2:

By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of decomposition?

"No, I can't entirely agree with the component illustrated in this puzzle. In my opinion, this puzzle illustrates more logical thinking and abstraction than decomposition. Students have to go through a process of elimination to figure out what the final code is, and to do so; they have to go through one row at a time, thus ignoring the other rows and only focussing on that particular row."

Question 3:

By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of pattern recognition?

"Yes, I agree. The puzzle clearly illustrates the component of pattern recognition because students have to provide the missing arrows on the diagram. To do that, they have first to figure out the overall pattern illustrated on the diagram."

Question 4:

By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of abstraction?

"Yes, I agree. The puzzle clearly illustrates the component of abstraction because students have to go through one row at a time to find where the five unique symbols are located. Thus, to do so, they only focus on that particular row, ignoring the other rows."

Question 5:

By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of decomposition?

"The puzzle, in my opinion, illustrates both the components of decomposition and abstraction. Students have to break down the puzzle into smaller steps: (1) they have first to solve the crossword puzzle, and (2) they have to use the answers of the crossword to identify what anti-virus icon to select. The abstraction component is illustrated where students have to search for the crossword answers; they are thus only looking at the information that would help them answer the crossword puzzle and not all the information presented to them."

Question 6:

By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of algorithmic thinking?

"Yes, I agree. The puzzle clearly illustrates the component of algorithmic thinking because students have to follow the algorithm on the screen to determine what the details are, to update the anti-virus software."

Question 7:

By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of pattern recognition?

"Yes, I agree. The puzzle clearly illustrates the component of pattern recognition because students have to follow the pattern of the flashing lights to determine what "mail" to open and which not to open."

Question 8:

In your opinion, what additional support (if any) is required to assist students in completing the computational thinking assessments apart from the virtual escape room?

"The virtual escape room is a great tool to teach students about computational thinking because it can encourage learning. I don't think that additional resources are required, but because there is no lecture presented at the start of the session, the puzzles must be evident in terms of the component you want to illustrate."

Question 9:

By examining the suggested VEscapeCT framework below, do you agree with the adjustments made to the framework compared to the original framework shown at the beginning of this interview?

" I can't entirely agree with the first adjustment you illustrated to me, splitting the User Type into User Type and User Requirement. You can keep everything as one step, but do proper research regarding the requirements students would need before completing the virtual escape room.

I agree with the second adjustment you illustrated, moving the Difficulty step from Participants to Puzzles. It is challenging to say upfront what the difficulty level would be of the puzzles because to create a challenging escape room; you want to create a puzzle that contains different difficulty levels, which can only be determined once you are busy with the design of the puzzles."

Question 10:

In your opinion, what other adjustments would you recommend for the VEscapeCT framework to further adjust it to the needs of a virtual escape room?

"I also think both the Location and Actos steps can be removed from the Virtual Equipment section because it won't be required for a virtual escape room. Apart from the first lecturer's suggestion of replacing the Location with Platform and the Actors with Virtual

Actors, I would add a Cost step for the Platform. Remember you are working with university students who may not be able to afford downloading software with a price attached to it to complete a virtual escape room. In this way, you can do research on platforms that would be the most cost-effective for students."

APPENDIX F

Themes

No	Question	Lecturer 1	Lecturer 2	Theme
1	**Looking at the questions set out in the pre-and post-test, would you agree that the questions are sufficient to access a student's computational thinking skills? Please motivate your answer.**	***"Yes, the questions are sufficient because, as an educator, the objective of any assessment is to encourage higher-order thought in the students, which is what you have achieved. You are starting at the lowest level, where you ask students to define each concept, and from there, you are building on that knowledge by asking them to apply what they have learned within the definition."***	*"Yes, I agree that the questions in both the pre-and post-test are sufficient to test a student's knowledge on computational thinking because you provide them with different levels of questions: (1) test whether they can define each concept, and (2) test whether they can apply that knowledge in an example"*	Encourage higher order thinking
2	**By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of decomposition?**	*"No, I can't entirely agree. The puzzle, in my opinion, illustrates more abstraction than decomposition because students have to focus on one row of numbers at a time to figure out what the final code is. They therefore only focus on that particular row, ignoring the other rows that are not important."*	*"No, I can't entirely agree with the component illustrated in this puzzle. In my opinion, this puzzle illustrates more logical thinking and abstraction than decomposition. Students have to go through a process of elimination to figure out what the final code is, and to do so; they have to go through one row at a time, thus ignoring the other rows and only focussing on that particular row."*	Encourage Logical Thinking
3	**By examining the puzzle below and the methods**	*"Yes, I agree. The puzzle clearly illustrates the concept of pattern*	*"Yes, I agree. The puzzle clearly illustrates the component of pattern*	Focus on Analyzing Trends

	used to solve it, do you agree that the puzzle effectively illustrates the component of pattern recognition?	*recognition because students have to complete the pattern on the screen by replacing the number on the diagram with the arrow that fits in the pattern."*	*recognition because students have to provide the missing arrows on the diagram. To do that, they have first to figure out the overall pattern illustrated on the diagram."*	
4	**By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of abstraction?**	*"Yes, I agree with the component illustrated in this puzzle because students have to go through each row of symbols to find the row containing the five unique symbols. As they do that, they only focus on that particular row, thus ignoring the other rows that are not important."*	*"Yes, I agree. The puzzle clearly illustrates the component of abstraction because students have to go through one row at a time to find where the five unique symbols are located. Thus, to do so, they only focus on that particular row, ignoring the other rows."*	Encourage Abstract Thinking
5	**By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of decomposition?**	*"This puzzle illustrates the concept of decomposition a bit better than the first challenge because the puzzle requires the student to (1) solve the crossword puzzle and (2) select the appropriate antivirus icon based on the answers in the crossword puzzle. Therefore, the student would have to divide this puzzle into smaller, more manageable steps to solve it. However, I feel abstraction is involved as well. When the students search for the crossword answers, they only focus on the information necessary to solve the*	*"The puzzle, in my opinion, illustrates both the components of decomposition and abstraction. Students have to break down the puzzle into smaller steps: (1) they have first to solve the crossword puzzle, and (2) they have to use the answers of the crossword to identify what anti-virus icon to select. The abstraction component is illustrated where students have to search for the crossword answers; they are thus only looking at the information that would help them answer the crossword puzzle and not all the information presented to*	Decomposing Problems

		crossword puzzle and not all the information presented."	*them."*	
6	**By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of algorithmic thinking?**	*"Yes, I agree. The puzzle clearly illustrates the concept of algorithmic thinking because students have to follow the algorithm on the screen to obtain the details necessary to update the anti-virus software."*	*"Yes, I agree. The puzzle clearly illustrates the component of algorithmic thinking because students have to follow the algorithm on the screen to determine what the details are, to update the anti-virus software."*	Encourage Algorithmic Thinking
7	**By examining the puzzle below and the methods used to solve it, do you agree that the puzzle effectively illustrates the component of pattern recognition?**	*"Yes, I agree. The puzzle clearly illustrates the concept of pattern recognition because students have to follow the pattern of the flashing lights to determine what "mail" to open and which to avoid."*	*"Yes, I agree. The puzzle clearly illustrates the component of pattern recognition because students have to follow the pattern of the flashing lights to determine what "mail" to open and which not to open."*	Focus on Analyzing Trends
8	**In your opinion, what additional support (if any) is required to assist students in completing the computational thinking assessments apart from the virtual escape room?**	*"The virtual escape room is a great tool to teach students about computational thinking because it can encourage learning and excitement. My only suggestion would be, especially for someone who has never heard about computational thinking, to implement a small introductory lesson at the start to provide them with a high-level overview of what computational thinking entails."*	*"The virtual escape room is a great tool to teach students about computational thinking because it can encourage learning. I don't think that additional resources are required, but because there is no lecture presented at the start of the session, the puzzles must be evident in terms of the component you want to illustrate."*	Transparency

9	**By examining the suggested VEscapeCT framework below, do you agree with the adjustments made to the framework compared to the original framework shown at the beginning of this interview?**	*"I would have to disagree regarding the first adjustment you illustrated to me, splitting the User Type into User Type and User Requirements. I think it can remain as one step in which you have to do proper research on what type of participants you will deal with and what requirements they would need to complete the virtual escape room.* *Regarding the second adjustment that you illustrated to me, moving the Difficulty from the Participants section to the Puzzle section, I agree with you because you can't determine the difficulty levels of the puzzles before the design of the puzzles. You can maybe determine upfront that the puzzles shouldn't be too difficult, but on the other hand, you also want to add that various difficulty levels to make the experience a challenge."*	*" I can't entirely agree with the first adjustment you illustrated to me, splitting the User Type into User Type and User Requirement. You can keep everything as one step, but do proper research regarding the requirements students would need before completing the virtual escape room.* *I agree with the second adjustment you illustrated, moving the Difficulty step from Participants to Puzzles. It is challenging to say upfront what the difficulty level would be of the puzzles because to create a challenging escape room; you want to create a puzzle that contains different difficulty levels, which can only be determined once you are busy with the design of the puzzles."*	Strategic placement of components
10	**In your opinion, what other adjustments would you recommend for the VEscapeCT framework to further adjust it to the needs of a virtual escape room?**	*"I suggest removing the Location and Actors steps under the Virtual Equipment section because they won't be required for a virtual escape room. Instead replace the Actors with Virtual*	*"I also think both the Location and Actos steps can be removed from the Virtual Equipment section because it won't be required for a virtual escape room. Apart from the first lecturer's*	Enhancements

		Actors and the Location with Platform."	*suggestion of replacing the Location with Platform and the Actors with Virtual Actors, I would add a Cost step for the Platform. Remember you are working with university students who may not be able to afford downloading software with a price attached to it to complete a virtual escape room. In this way, you can do research on platforms that would be the most cost-effective for students."*	

Table 46: Themes

APPENDIX G

Pre-and Post-Test Averages

Students with INF 113

Pre-Test Questionnaire

Question Number	1	2	3	4	Number of Students that selected correct answer	Percentage of Students that selected correct answer	Correct Answer	Total Students
Q1	0	3	33	0	33	92%	3	36
Q2	9	3	0	24	24	67%	4	36
Q3	0	1	2	33	33	92%	4	36
Q4	36	0	0	0	36	100%	1	36
Q5	0	0	2	34	34	94%	4	36
Q6	0	0	1	35	35	97%	4	36
Q7	3	8	25	0	25	69%	3	36
Q8	0	29	2	5	29	81%	2	36
Q9	4	4	9	19	19	53%	4	36
Q10	1	4	31	0	31	86%	3	36
Q11	34	0	1	1	34	94%	1	36
Q12	3	9	1	23	23	64%	4	36
AVERAGE						82%		

Table 47: Pre-Test (Students with INF 113)

Post-Test Questionnaire

Question Number	1	2	3	4	Number of Students that selected correct answer	Percentage of Students that selected correct answer	Correct Answer	Total Students
Q1	0	0	36	0	36	100%	3	36
Q2	8	1	0	27	27	75%	4	36
Q3	0	0	2	34	34	94%	4	36
Q4	34	0	2	0	34	94%	1	36
Q5	0	0	1	35	35	97%	4	36
Q6	0	0	1	35	35	97%	4	36
Q7	0	7	27	2	27	75%	3	36
Q8	1	30	1	4	30	83%	2	36
Q9	4	0	11	21	21	58%	4	36
Q10	2	1	33	0	33	92%	3	36
Q11	33	0	1	2	33	92%	1	36
Q12	1	10	2	23	23	64%	4	36
AVERAGE						85%		

Table 48: Post-Test (Students with INF 113)

Students without INF 113

Pre-Test Questionnaire

Question Number	1	2	3	4	Number of Students that selected correct answer	Percentage of Students that selected correct answer	Correct Answer	Total Students
Q1	0	3	23	0	23	88%	3	26
Q2	12	0	0	14	14	54%	4	26
Q3	0	0	11	15	15	58%	4	26
Q4	23	0	3	0	23	88%	1	26
Q5	0	0	0	26	26	100%	4	26
Q6	0	1	0	25	25	96%	4	26
Q7	0	4	22	0	22	85%	3	26
Q8	1	17	1	7	17	65%	2	26
Q9	2	4	7	13	13	50%	4	26
Q10	1	2	23	0	23	88%	3	26
Q11	25	1	0	0	25	96%	1	26
Q12	0	12	0	14	14	54%	4	26
AVERAGE						77%		

Table 49: Pre-Test (Students without INF 113)

Post-Test Questionnaire

Question Number	1	2	3	4	Number of Students that selected correct answer	Percentage of Students that selected correct answer	Correct Answer	Total Students
Q1	0	3	23	0	23	88%	3	26
Q2	10	0	0	16	16	62%	4	26
Q3	0	0	3	23	23	88%	4	26
Q4	25	0	0	1	25	96%	1	26
Q5	1	0	0	25	25	96%	4	26
Q6	0	1	1	24	24	92%	4	26
Q7	0	5	21	0	21	81%	3	26
Q8	1	19	0	6	19	73%	2	26
Q9	5	2	7	12	12	46%	4	26
Q10	0	2	24	0	24	92%	3	26
Q11	24	0	1	1	24	92%	1	26
Q12	0	10	1	15	15	58%	4	26
AVERAGE						80%		

Table 50: Post-Test (Students without INF 113)

APPENDIX H

Pre-and Post-Test Questionnaire Key

		KEY (Options)			
No.	**Question**	**1**	**2**	**3**	**4**
Q1.1	What is computational thinking?	The way computers think	A problem-solving approach that only computer scientists use, that involves expressing problems in a way that computers can understand	A problem-solving approach that can be used by anyone, that involves expressing problems in a way that computers can understand	The way computers follow instructions
Q1.2	Which of the following is an example of computational thinking?	Sorting important documents	Choosing a line at the supermarket	Running Errands	All of the above
Q1.3	In which of the following disciplines can computational thinking be applied?	English Literature	Mathematics	Computer Science	All of the above
Q1.4	What is decomposition?	Breaking a big problem into smaller problems that are easier to solve	Removing necessary details in a problem	Breaking a big problem into smaller problems that challenges our way of thinking	Removing unnecessary details in a problem
Q1.5	What is an example of decomposition?	Baking a cake	Looking at what different kinds of cakes can be made	Thinking about how we can make it the best cake	When baking a cake, thinking about what ingredients to get together, what the method is and how the cake should be decorate
Q1.6	What is pattern recognition?	Removing necessary details from a problem	Identifying differences in problems	Removing unnecessary details from a problem	Identifying similarities in problems
Q1.7	What is an example of pattern recognition?	Uploading a photo to Facebook	Facebook's Location Services	Facebook's Facial Recognition	Uploading a photo to Instagram
Q1.8	What is abstraction?	Drawing conclusions from problems by applying abstract thinking	Simplifying a problem by only dealing with the important details and neglecting the unnecessary details	Simplifying a problem by only dealing with the unimportant details and neglecting the necessary details	Drawing important details from problems by applying abstract thinking
Q1.9	What is an example of abstraction?	A map	A house plan	A sign of an aisle in a store	All of the above
Q1.10	What is algorithmic design?	Developing the necessary input to solve a problem	Developing the necessary processing to solve a problem	Developing the necessary step-by step solution to solve a problem	Developing the necessary output to solve a problem

Q1.11	What is an example of algorithmic design?	An installation manual	A comic strip	A map	A list of items on sale
Q1.12	What is Evaluation?	Evaluating solutions for any similarities	Evaluating solutions against desired outcomes	Evaluating certain parts of the solution	All of the above