

THE BEE-BOT IN THE ASSESSMENT FOR LEARNING OF MATHEMATICAL CONCEPTS

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Abstract

Sue Ellen Gambin

The Bee-Bot in the Assessment for Learning of Mathematical Concepts

This research was conducted in one Maltese State Primary school using a constructivist grounded theory approach. The study analysed the perceptions of educational leaders, educators, and pupils of the Bee-Bot's role in Mathematics teaching, assessment, and learning. To acquire empirical data, interviews and focus groups were utilised. To generate an in-depth analysis, the participants were intentionally selected from different levels. The interview findings revealed the educational leaders' and educators' views on the Bee-Bot's impact and contribution in teaching Mathematics. Meanwhile, the focus group findings indicated the pupils' views on the Bee-Bot's integration into mathematical learning as pupils apply critical and computational thinking abilities. The study concluded with recommendations, highlighting what classroom and support teachers value most about utilising technology for Mathematics and its formative assessment. Knowledge gaps were further identified, hence suggesting additional necessary intervention for Bee-Bot integration. Another recommendation was to investigate how parents' opinions affect children's views on the Bee-Bot in Mathematics.

Master of Education in eLearning

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Grounded Theory

Bee-Bot

Technology

Qualitative Research

Formative Assessment

Mathematical

Dedication

*This research is dedicated to my husband, Alston,
for his continuous support, love, and patience,
and to our two children, Yannick and Nakadia.
I hope it will inspire you to never give up on your goals
and to never doubt your ability to succeed
if you put in the time and effort.*

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List of Abbreviations

TTS	Teacher Technology Solution
TPCK	Technological Pedagogical Content Knowledge
TPACK	Technology, Pedagogy, and Content Knowledge
AMTE	Association for Mathematics Teacher Educators
NAO	National Audit Office
STEM	Science, Technology, Engineering and Maths
CRiMSE	Centre for Research in Mathematics and Science Education
ICT	Information and Communications Technology
CoPE	Community of Professional Educators
CT	Curriculum Time
EO	Education Officer
ER	Educational Robotics
ISTE	International Society for Technology and Education

Chapter 1

INTRODUCTION

One might say the computer is being used to program the child. In my vision, the child programs the computer and, in doing so, both acquires a sense of mastery over a piece of the most modern and powerful technology and establishes an intimate contact with some of the deepest ideas from science, from mathematics, and from the art of intellectual model building (Papert, 1980, p. 5).

1.1 Introducing the Study

The study focuses on the perspectives of educators¹ and pupils on the Bee-Bot's use for the assessment for learning of mathematical concepts. This chapter outlines the study's aims and the expected outcomes, and provides a short description of each chapter. Through existing literature, it is possible to provide a brief description of the opportunities and benefits of utilising the Bee-Bot, as well as the limitations and setbacks educators may encounter.

The literature review discusses the advantages of robotic devices, technology-enhanced learning, and the assessment for learning of mathematical concepts, while focusing on technology-enhanced learning discoveries in Maltese schools. The chapter also outlines how educators are supported and constrained when they use the Bee-Bot for teaching and learning. Additionally, it provides a review of existing literature on how gender

¹ The term "educators" refers to educational leaders, the Senior Leadership Team and teachers.

affects learning with the Bee-Bot. This research portrays the existence of many ways of assessing mathematical topics using the Bee-Bot, and considers the participants' viewpoints and interpretations.

1.2 Statement of the Problem

Currently, the use of technology has become an everyday occurrence both at home and at work (Barr, Gillard, Firth, Scrymgour, Welford, Lomax-Smith, Bartlett, Pike & Constable, 2008). Children today are very good at using technology since they are exposed to digital devices at a very young age (Camilleri, 2019; Harwood, 2017). This study is thus directed in investigating the educational leaders', educators', and pupils' perceptions of the effectiveness of technology-enhanced assessment of mathematical concepts. When students' learning is enhanced with robotic tasks, young pupils manage to enrich their mathematical problem-solving competences (Cervera, Diago, Orcos and Yáñez, 2020).

It is understandable to expect technology use in the classroom setting, even as early as the Early Years classes (Ertmer & Ottenbreit-Leftwich, 2010). Other authors note that the use of technology can benefit the teaching and learning of students (Baroutsis, White, Ferdinands, Lambert & Goldsmith, 2019). Therefore, it is reasonable for the teacher to use technology to identify where students are in the learning process (Dalby & Swan, 2019), while becoming and feeling confident using it, such as the case of Bee-Bot, for formative assessment (Looney, 2010).

Technological tools can support the scaffolding of learning, and aid the child in moving on to the next level of learning (Sharma & Hannafin, 2007). The benefits of technological devices are emphasised by Bereczki and Kárpáti (2021), who maintain that “technology can be a powerful tool to support students’ creativity-relevant motivation and

engagement, idea development and exploration, creation, as well as to promote authentic assessment practices” (p. 20). The literature review in Chapter 2 identifies a research gap in the effectiveness of the Bee-Bot in assessing for learning. Therefore, this study seeks to partly fill this gap, while striving to explain how the Bee-Bot is utilised by Primary Year One teachers for formative assessment.

As Cervera et al. (2020) state, there are simple and easy ways to use robotics that are constructed with a purpose for coding to be employed with Early Years pupils. However, Camilleri (2017) and Angeli and Valanides (2020) caution that it is critical for teachers to understand how to use the Bee-Bot in a pedagogically sound manner so that students' computational thinking skills develop to their full potential. This study also seeks to explain how educational leaders, educators and pupils view this programmable robot as a complement and enhancement of the strategies for the assessment for learning. Teachers assess for learning continuously to determine where their students are in their learning process, subsequently giving feedback and formulating teaching and learning strategies to guide their students to continue building their learning upon their current state, a process that is commonly referred to as formative assessment (Said Pace, 2016).

Nonetheless, there is still the need for more research to investigate the views of educational leaders, educators, and pupils, particularly on the technological techniques adopted by teachers to improve assessment, and why they use technology for assessment enrichment, as described, for example, by Looney (2010). Another important aspect identified by Håkansson Lindqvist (2019) is what school leaders put into practice as this influences the school's stakeholders' willingness to make use of digital technologies.

1.3 Purpose of the Study

This study recognises that there are various perspectives on assessment for learning of mathematics when utilising the Bee-Bot. This study's purpose is thus to increase knowledge and enhance an understanding of how the Bee-Bot can be utilised for formative assessment of mathematical concepts. This study further aims to create more awareness and appreciation of the Bee-Bot's efficacy in mathematical learning.

The Bee-Bot, which was developed by the TTS² group, "is a big bee that pupils can program by pushing buttons on its back for moving forward, backward, turning left, right, starting to move or deleting previous commands" (Beraza, Pina and Demo, 2010, p. 551).

This study adopts a constructivist interpretivist approach to investigate the efficacy of the Bee-Bot in the assessment of learning of mathematical concepts. This approach was also selected so that the participants' different views and interpretations are valued, while also limiting this researcher's possible impact on the gathered data and its analysis (Charmaz, 2006). As Vancell (2013) states, a constructivist approach acknowledges the person's ability to generate new knowledge. This investigation thus adopts a constructivist grounded theory methodology that permits self-reflexivity for the researcher (Birks & Mills, 2015). Indeed, through self-reflexivity, the researcher keeps her assumptions in check, and minimises their influence on the gathered data and its analysis (Gentles, Jack, Nicholas & McKibbon, 2014).

As suggested by Glaser and Strauss (2006), this researcher utilises a grounded theory methodology to collect and analyse empirically rich data from participants concerning their

² TTS stands for Teacher Technology Solutions and it is a trademark and trade name owned by RM Educational Resources Ltd.

impressions of the Bee-Bot's use and its usefulness in assessing Year One pupils' mathematics learning. The findings of this investigation provide useful information to the readers of this study, allowing them to have a better understanding of the many techniques used to assess for learning of mathematical concepts, as well as the Bee-Bot's usefulness in these evaluations.

Furthermore, the study discusses the educators' perceptions of the necessary support they need for effective pedagogical teaching and learning of mathematical skills using the Bee-Bot.

1.4 Research Questions

Bluff (2005) argues that “[t]he research question identifies the phenomenon to be studied” (p. 150), and thus, the research design should best reflect the research questions (Chun Tie, Birks & Francis, 2019). Bluff (2005) further recommends that “[t]he area of the study needs to be broad, at least initially” (p. 150), while Corbin and Strauss (2008) insist that the research questions must be phrased in a way that the researcher has enough independence and ease to examine a topic in depth.

Meanwhile, Charmaz (2006) suggests that the research methods should be selected in a way that allows the researcher to answer the research questions with creativity and precision. This researcher followed Charmaz's (2006) advice and used techniques that helped her find answers to her “research questions with ingenuity and incisiveness” (p. 15), while bearing in mind that the data collection methods have an effect on the “phenomena you will see, how, where, and when you will view them, and what sense you will make of them” (p. 15). In Grounded Theory, patterns that emerge in the data clarify the research questions (Engward, 2013).

The following main research question is the focus of this study:

- What are the perceptions of children and professionals about the effectiveness of the Bee-Bot in the assessment for learning of mathematical concepts?

This research addresses two secondary questions that help answer this fundamental question:

- In what way is the Bee-Bot enhancing the teaching and learning process?
- What are the pedagogical advantages and disadvantages of the Bee-Bot?

1.5 Overview of the Chapters

Using a constructivist grounded theory approach, this dissertation comprises six chapters. Chapter 1 introduces the study and provides an overview of the problem. The study's aim to investigate the educators' and pupils' perspectives on the assessment for learning of mathematics with the Bee-Bot, an introduction to the study's main research question, additional subsidiary questions and a summary of the subsequent chapters.

Chapter 2 explores the literature concerned with the Bee-Bot's implementation in mathematical activities and its effectiveness in assessing for learning of mathematics in Early Years classrooms. The study is particularly focused towards literature that gives importance to how educators utilise the Bee-Bot for the assessment of learning and how technology impacts the learning environment.

Subsequently, Chapter 3 provides a discussion of this study's methodology, as well as the research instruments employed. This research examines educators' and pupils' perspectives on how the Bee-Bot impacts their teaching and learning, how it may be used

for formative assessment and its pedagogical benefits and drawbacks. This chapter further analyses data validity and reliability, while presenting the study's ethical considerations.

Chapter 4 provides the empirical findings of the gathered data and the relevant literature to "establish a context for the study" (Birks, Hoare & Mills, 2019, p. 4). The chapter contains excerpts from the participants' interviews to "contribute to the descriptive nature of qualitative research" (Merriam & Tisdell, 2016, p. 18). This study's findings are presented as a storyline, enabling this "researcher to present the theoretical products of their research in an interesting and creative way without diminishing the credibility, validity or merit of their work" (Birks, Mills, Francis & Chapman, 2009, p. 416).

Chapter 5 is a detailed analysis of the research findings. Through constant comparison recurring themes and patterns were uncovered through the data analysis, which took place throughout the research process as suggested by Charmaz (2006). The analysis was built on the recurring themes and the connections discovered between them (Merriam & Tisdell, 2016).

The last chapter, Chapter 6, compares the study's major findings in relation to the research questions. It discusses the advantages and disadvantages of the study's subject matter. In this last chapter, the reader gets a better grasp of how the Bee-Bot is used to measure mathematical concept acquisition, as well as a greater awareness of the efficacy of Bee-Bot-enhanced mathematical learning. This last chapter also includes recommendations for further studies.

1.6 Conclusion

This chapter described the structure of this investigation and dissertation. With the goal of providing a clearer sense of the nature of the study, this chapter established the intent of the research, objectives, and extent to which the research area will be explored. The chapter further introduced the approach employed to gather insightful and rich data on the educators' and pupils' views of the efficacy of the Bee-Bot for the assessment for learning of mathematical concepts.

Chapter 2

LITERATURE REVIEW

Sally had just finished an interview with the researcher, who had been interviewing her about programmable toys. In the interview Sally had tried to make the toy Bee-Bot move in a circle, and had been puzzled when she was not able to. When the interview was finished she asked if she could play with the toy for a while. She took the toy away by herself and tried to make it dance. While doing this, she experimented with the buttons and discovered what each did. She sat down next to the toy and watched its actions from various angles, lying beside it and manoeuvring the toy. After approximately ten minutes, "I can do it!" she called, and with great delight rushed to show the researcher how to make the toy move in a circle (Highfield & Mulligan, 2008, p. 5).

2.1 Introduction

This literature review discusses the Bee-Bot and the educators' and the pupils' perspectives on its use in Primary Year One classrooms. This investigation critically explores how pupils create knowledge when technology is used, notably the Bee-Bot, for teaching and learning. Therefore, the study investigates how teachers use this technology for assessment for learning, that is, "where assessment is used not as an end but as a means to gain information on which to plan for future learning" (Ministry for Education, 2015, p. 33).

According to Slentz, Early and McKenna (2008) the “assessment of youngsters as they participate in daily activities, routines, and interactions generally produces the most valuable information for assessment” (p. 12). Therefore, the authors add that the assessment methods used by teachers “should allow for observation of young children engaged in spontaneous behaviours in familiar settings and with familiar people” (p. 12).

The application of technology in the teaching of mathematics in Malta has received very little research interest. The study by Xerri (2012) is one of the few investigations offering insight into how robotic devices, including the Bee-Bot, are used for mathematical activities in the Early Years in Maltese State Primary schools. The author explored the benefits and limitations encountered when implementing the Bee-Bot in mathematical tasks.

This researcher’s experience in the classroom, as well as contemporary teaching and learning critical evaluations, indicate that a constructivist approach enables assessment for learning since the learner engages in natural and unplanned behaviour and learns by constructing meaning to his/her experiences. This is further elaborated by Hein (1991). This chapter presents evidence that demonstrates that social constructivist literature supports the Bee-Bot’s use in Early Years classrooms for active mathematics learning.

Unfortunately, there is a huge gap between local and international research in this field. This study thus attempts to partly fill this gap.

2.2 The Social Constructivist Approach

Ernest (1991) contends that, in the view of social constructivists, learning, and particularly mastery of mathematics, is a social construction. It is the author’s contention

that a social constructivist theory of learning mathematics recognises that both social processes and the meaning offered by an individual perform a vital and crucial part in the process of acquiring mathematical knowledge.

Vygotsky, a “pioneer of social constructivism” (Liu & Chen, 2010, p. 64; Kaplan, 2017), through his social learning theory, argues that psychological phenomena are thought to be the result of social interaction. For their part, McRobbie and Tobin (1997) explain that, when looking at something from a specific perspective, there are a variety of approaches that people might use to arrive at their own conclusions. According to the authors, students should be in command of their own learning and should thus use what they already know to make sense of what they are presently experiencing.

Meanwhile, Dewey (1986) argues that learning is a dynamic process that changes as one's experiences grow and develop, adding that this relies heavily on active learning. He adds that, to create knowledge, one must first absorb and reconstruct reality. Instead of only receiving knowledge from the teacher, students should be actively engaged in intellectual reflection of their own. Similarly, Papert (1993) believes that learning occurs best when the learner has most control over the learning process, noting that, when compared with the concept of knowledge transmission by the teacher to the student, the picture of learning as the development of one's own knowledge is quite important and powerful.

McLoughlin (1999) explains that scaffolding is a concept first created by Bruner, Wood and Ross in 1976 to describe the successful involvement of an adult or tutor in another individual's learning process. The author adds that scaffolding in technology-supported environments has extended to encompass a wide range of new types of

assistance, while increasing student accountability. As the author also argues, while the theoretical foundation provided by Vygotskian theory establishes a clear link between social engagement and cognitive development, technology can allow students to work on their cognitive growth and skill improvement.

Papert (1980) believes in the concept of technology in mathematics, suggesting that, via programming, a child may have direct touch with some of mathematics' most profound ideas. Meanwhile, Hausfather (1996) maintains that teachers can, with the help of scaffolding, assist children in improving and expanding their current abilities and knowledge. According to Hausfather (1996), Vygotsky viewed learning as a process that leads to development, rather than a product of development.

Meanwhile, Kaplan (2017) argues that teachers may get vital insights on their students' diverse needs via the use of technological tools, while freeing up teacher time for one-to-one sessions with each student. Cicconi (2014) observes that the research by Vygotsky shows that collaboration is essential in early childhood education via his theory of social learning. The author adds that collaboration is critical for student success in the early stages of mathematical education, concluding that early childhood educators may use technology to foster collaborative learning in the classroom.

According to Fischer and Hencke (1996), Piaget is "known as a child psychologist; nevertheless, he is also a zoologist, a mathematician, and a philosopher; but perhaps, above all, he is a genetic epistemologist" (Richmond, 2006, p. 1), emphasising that newborns actively construct their own worlds and that physical and social circumstances impact that construction. This is supported by Piaget's (1952) cognitive development theory that states that people cannot just be handed information and are expected to understand and use it,

but rather, people must create their own understanding through what they experience.

Hausfather (1996) points out that individuals construct meaning when new information is combined with previously acquired knowledge.

As Mikropoulos and Bellou (2013) assert, individuals use information and technology in practically every area of their lives. According to Littlejohn and Pegler (2007), empirical findings recommend that technology-enhanced learning (TEL) that uses computers and other technology improves traditional teaching techniques by encouraging students to participate more actively in the learning process (Lam, Ng, Tse, Lu & Wong, 2021). This consequently “accelerates ‘learning by doing’ and ‘learning by design’” (Gorakhnath & Padmanabhan, 2017, p. 222).

According to Camilleri (2017) and Tang, Tung and Cheng (2020), when educational robots are used as a pedagogical tool, educators have the potential to influence or change the way students and teachers interact and the dynamics of that interaction have an impact on the students' knowledge growth. According to the study by Lee, Sullivan and Bers (2013), children who took part in unstructured constructionist robotics tasks worked significantly more collaboratively than those who participated in more structured tasks. The researchers observe that strong social bonds can be built more efficiently in a constructionist learning environment, where children are given the option to play and learn using technology.

Lam et al. (2021) assert that TEL is intended to assist teachers in developing a variety of instructional approaches that are adapted to the specific needs of learning of each individual student. The authors suggest that TEL enables students to become independent learners who actively investigate the subject matter, while identifying their own learning

aims and satisfying their specific learning requirements as they study and grow together cooperatively and competitively.

Meanwhile, Hardman (2019) contends that technology has the potential to improve Primary school students' mathematics performance if technology is utilised in conjunction with a constructivist pedagogy, as opposed to traditional pedagogy. According to Nagappan (2002), Piaget regarded mathematical reasoning and logic to be the most advanced cognitive functions. For Busuttil and Farrugia (2020), the significant increase in investment in education technology across Europe aims to build on constructivist and constructionist epistemologies, to strengthen students' digital and coding skills and to support creative and higher-order thinking and participatory leadership. Mikropoulos and Bellou (2013) also contend that educational robotics provide “an approach to educational technology that fits constructivism” (p. 6).

Casler-Failing's (2021) findings indicate that robots encourage children to investigate the way things function, which would effectively help their mathematical analytical thinking abilities. Meanwhile, Alimisis, Moro, Arlegui, Pina, Frangou and Papanikolaou (2007) claim that, in addition to students being able to study at their own pace, digital technology facilitates the creation of learning environments that encourage students to participate and interact with others. According to Dalby and Swan (2019), through technology use in mathematics classrooms, comprehensive formative assessment methods may be constructed to enhance learning.

Moreover, Palincsar (1998) notes that learning occurs because of the learner's viewpoints and encounters thereby being able to examine his/her preconceptions and investigate new ideas. The author further observes that, according to Vygotsky, to

understand cognition, one must analyse the impact that participation in common pursuits has on one's engagement in other activities and that the application of previously learned concepts and principles is necessary for effective development. Elwood (2006) explains that, using assessment to help learners improve their own self-and peer-evaluation skills, as well as training them to recognise their own learning, are an incredible approach to promote students' performance in school and raise their long-term learning capacities.

2.3 Learning and Formative Assessment – How They Complement Each Other

Ambrose, Bridges, DiPietro, Lovett and Norman (2010) believe that “[l]earning is a process, not a product ... involv[ing] change in knowledge, beliefs, behaviors, or attitudes ... [and] ... [i]t is the direct result of how students interpret and respond to their experiences — conscious and unconscious, past and present” (p. 3).

For their part, Weurlander, Söderberg, Scheja, Hult and Wernerson (2012) argue that learning tools like formative assessment are useful because they may improve both the learning process and its end outcome. Black and Wiliam (2010, p. 82) maintain that the phrase ‘formative assessment’ is applied

to refer to all those activities undertaken by teachers — and by their students in assessing themselves — that provide information to be used as feedback to modify teaching and learning activities. Such assessment becomes formative assessment when the evidence is used to adapt the teaching to meet student needs.

Hattie and Jaeger (1998) claim that, transferring knowledge to students, assessing their retention and adjusting the next stage of learning depending on their comprehension are the core of the teaching and learning strategy. According to Weurlander et al. (2012),

assessments provide a strong warning about the kind of information that is valued in a lesson. Similarly, Jacoby, Heugh, Bax and Branford-White (2014) emphasise that, “[t]eaching guided by formative assessment allows the student to focus on the learning they need to derive from their particular subject area” (p. 73).

According to Hattie and Jaeger (1998), feedback is the most influential factor in boosting performance. For instance, students benefit more from homework when they get feedback thereby increasing the likelihood that learning will take place (Hattie & Jaeger, 1998).

2.4 Robotic Devices and Technology Enhanced Learning (TEL)

As Spector, Ifenthaler, Sampson, Yang, Mukama, Warusavitarana, Dona, Eichhorn, Fluck, Huang, Bridges, Lu, Ren, Gui, Deneen, San Diego and Gibson (2016) observe, “nearly all learning environments in the 21st century involve and depend on digital technologies” (p. 61). Papert (1980) believes that the use of computational technology provides the child with innovative ways to learn, think, and develop emotionally and cognitively.

Technology-enhanced learning is a phrase that seeks to establish an ideological viewpoint on the link between technology, education, the individual, and the social system (Bayne, 2015). Bayne (2015) maintains that, as digital educators, less emphasis should be placed on how technology is utilised in education and more emphasis on how technology is used to achieve educational goals. Indeed, Bers (2010) asserts that, creating digital settings that enable children to build a personal sense of identity that is based on moral values is critical to engaging children in using technology to make the world a more beautiful place. According to the author, when technology is brought into the learning process, active participation improves significantly.

Papert (1980) believes that, in a computer-rich future, much of what we view as excessively rigid or overly technical would be attainable and accessible to students. Daniela and Lytras (2019) describe how Papert (1984), nearly forty years ago, was the first researcher to bring up the idea of utilising robots in the classroom, noting that students may build their mathematical knowledge with the use of computers in the learning process. According to Lathifah, Budiyanto and Yuana (2019), the use of robotics in the classroom helps students learn better because it emphasises the role of creators and designers, while also allowing them to connect with actual problem-solving challenges. According to the authors, “[t]he background of educational robotics is constructivist learning. Constructivist learning provides direct exploration and design experience using tools that provide opportunities for students to understand concepts” (pp. 020053-4).

Highfield (2010) suggests that, when tasks involving robotic toys have more than one solution to reach the activity’s aim, these encourage pupils to think flexibly and adopt reflective thinking methods. For their part, Bers, Seddighin and Sullivan (2013) state that students may use educational robotics to integrate math and scientific topics in the classroom by using coding and other technological tools. Cervera et al. (2020) contend that the Bee-Bot offers the teacher and pupils a variety of coding commands to interact with the device.

According to Spector et al. (2016), attention and engagement are more likely to be maintained when technological tools are used. Meanwhile, Ioannou, Socratous and Nikolaedou (2018) suggest that relevant resources should be created to support already available educational robotic devices to become part of the school curriculum. Drijvers (2015) claims that a good design of the digital tool, corresponding activities and teaching

makes it easier to both learn how to use digital technology to solve math problems and come up with mental schemes that include an understanding of the math at hand. The author adds that, digital technology should be incorporated into a cohesive educational setting, where students' use of technology is taken into consideration while assessing their progress.

For O'Hara (2008), when technology is properly used, it provides the pupils with improved and extended forms of play, adding that technology implementation in teaching and learning is a powerful pedagogic instrument. According to Bers (2010), it is important that teachers encourage young children to participate in active and interactive learning activities by constructing and programming physical robotic devices. Furthermore, Beraza et al. (2010) contend that children consider robotics as a form of play, and thus, with robotics, children begin to become familiar with programming (Figure 2.1).

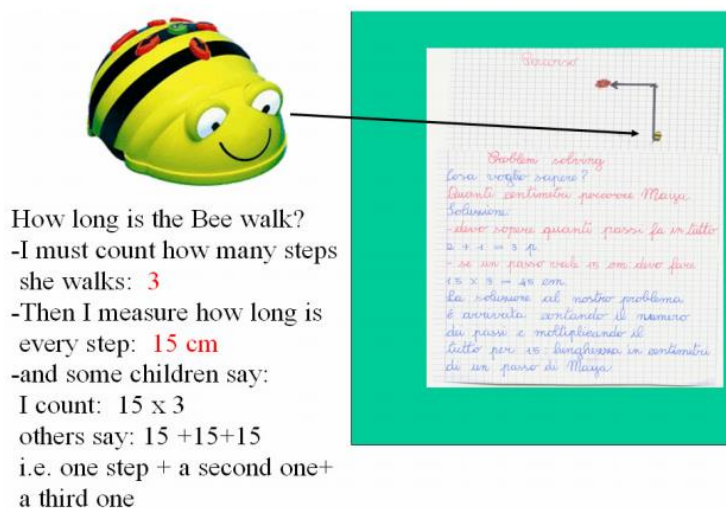


Figure 2.1: Students programme the Bee-Bot (Source: Beraza et al., 2010)

According to Kalelioglu and Sentence (2020), using various types of physical gadgets can assist students in learning new programming approaches and improving their

programming skills (Kalelioglu & Sentance, 2020). Hunsaker (2018) describes robots as “a bridge between the virtual (programming/coding) world and the physical (tangible) world” (p. 7).

2.4.1 Technology-Enhanced Assessment of Mathematics

According to the National Research Council, Board on Mathematical Sciences and Their Applications, & Mathematical Sciences Education Board (1989), only when students’ grasp of mathematics has been extended as a result of their own in-depth investigation does the subject become valuable to them. The report asserts that technology should not be employed simply because it is enticing, but also because it can help students learn mathematics more effectively by enhancing their own mathematical abilities.

Papert (1980) contends that young children from the earliest stages of life are continually mining and synthesising mathematical knowledge from their surroundings and from interactions between their bodies and the environment around them, as demonstrated by Jean Piaget's work in genetic epistemology. The author further notes that, “although most of our society classifies mathematics as the least accessible kind of knowledge, it is, paradoxically, the most accessible to children” (p. 135). Due to the advanced technology available to teachers, students may improve their mathematical problem-solving skills by engaging in computing-related activities in the classroom setting (Cervera et al., 2020).

Catlin and Blamires (2010) state that the use of robotics as learning tools allow each student to reach conclusions in his or her own way. Robotics in the classroom also provides assistance to children who are having difficulty with their academic pursuits, while providing

encouragement to advanced students. Messer, Thomas, Holliman and Kucirkova (2018) indeed argue that considerable improvement in mathematical ability and spatial awareness may be achieved by maintaining a rudimentary understanding of programming and participating in simple programming tasks. Furthermore, Highfield, Mulligan and Hedberg (2008) suggest that young children can learn mathematical concepts and cognitive processes by programming digital robots and then watching them perform a series of stored instructions.

As Lopez-Caudana, Ramirez-Montoya, Martínez-Pérez and Rodríguez-Abitia (2020) affirm, robotics is one of several technologies that may be utilised to assist in mathematics learning processes, concluding that an “implementation of visual and technological resources has had good results in the teaching-learning process of Mathematics” (p. 7). Similarly, Catlin and Blamires (2010) provide an example of a negative number mathematical equation, observing that, when children use robots that they are already familiar with, they help them to use their visual, kinaesthetic and spatial modalities to develop models of thought and better grasp the negative number equation.

As Spector et al. (2016) observe, educational engagement and formative assessments have the potential to be improved by using the various learning technological tools. Meanwhile, according to OECD/CERI (2008), “[i]n classrooms, formative assessment refers to frequent, interactive assessments of student progress and understanding to identify learning needs and adjust teaching appropriately” (p. 1). Information about students’ thoughts or performance is gathered early on in formative assessment activities. Consequently, this information is used to inform future assessments,

and the ultimate influence on student learning is determined by how this knowledge is applied (Dalby & Swan, 2019).

2.4.2 The Model for Mathematics Teacher TPACK Standards and Development

Niess, Ronau, Shafer, Driskell, Harper, Johnston, Browning, Özgün-Koca and Kersaint (2009) believe that the primary goal of using mathematical digital technology is to demonstrate and validate ideas produced in the classroom. For their part, Havlásková, Homanová, Kostolányová and Barteček (2019) emphasise that today's educators should not only be subject matter experts but should also apply relevant instructional and methodological approaches and integrate technology into their teaching. The TPCK³ is a model that represents this approach to the teachers' pedagogy (Koehler & Mishra, 2005).

Niess et al. (2009) states that the Technology, Pedagogy, and Content Knowledge (TPACK) Standards for Mathematics Teachers provide a framework to investigate the relationships within and amongst these three areas of competence. TPACK⁴ gives educators a flexible lens through which to examine the expertise they bring to the table as they create curricula and lessons that get kids ready to think mathematically and learn through digital means. Niess et al. (2009, p. 13) state:

Principals and professional development consultants, with specific work guided by TPACK, are able to plan more informed and directed professional development for groups of teachers, as well as evaluate the effectiveness of their programs. Teacher

³ TPCK stands for Technological Pedagogical Content Knowledge.

⁴ TPACK stands for Technology, Pedagogy, and Content Knowledge.

educators might find the TPACK levels helpful in evaluating and planning the technology preparation of their preservice and in-service students.

Niess et al. (2009) explain that TPACK is a term used to describe the growing body of information that teachers have because of “the strict intersection between the three individual knowledge constructs of technology, pedagogy, and subject matter content” (p. 7). They add that, as part of the TPACK development process, the AMTE⁵ Technology Committee chose to break down teacher levels of thinking and knowledge. According to the authors, the TPACK Development Model for Mathematics Teachers was further structured by four primary themes, and the Technology Committee agreed to group these themes, thus providing descriptors. These are Curriculum and Assessment, Learning, Teaching, and Access. The Technology Committee opted to combine Curriculum and Assessment into one group in order to emphasise the interconnected nature of curricular and assessment decisions (Niess et al., 2009). Niess et al. (2009, p. 12) note:

As an example of how the Curriculum and Assessment theme engages the shift in mathematics subject matter, consider teachers who initially recognize that technology can be used to support mathematical processes such as square root.

The Mathematical TPACK Development Model is a framework for teachers who want to incorporate technology into their education to improve student outcomes (Niess et al., 2009).

⁵ AMTE stands for the Association for Mathematics Teacher Educators that worked for improving mathematics teachers' technology preparedness.

Niess et al. (2009) further observe that, in accordance with the suggested Mathematics Teacher TPACK, teachers can benefit from utilising technology to assist them in enhancing their productivity, while also increasing their professionalism. The authors add that teachers may research and evaluate existing and forthcoming technology to improve the academic mathematics success of all students in the classroom. Indeed, they state that teachers may show and encourage techniques for using technology safely, legally and ethically to engage with and discover mathematics to students, parents and co-workers.

In fact, the proposed Mathematics Teacher TPACK indicates that technology can assist in the implementation of several effective assessment and evaluation procedures. Meanwhile, Niess et al. (2009) suggest that teachers may employ appropriate technology to correctly assess all their students' mathematical comprehension, analyse results and communicate findings in a variety of ways. The authors state that teachers can even provide technological correlation between assessments and math classroom activities.

Niess et al. (2009) continue that, according to the proposed Mathematics Teachers TPACK Standards and Indicators, to keep abreast of new and emerging digital age communication resources, teachers should frequently take part in new and continuous professional activities that leverage new and emerging technology to increase their knowledge of technological, pedagogical and content issues related to promoting student development and imagination in mathematics.

2.5 Technology Enhanced Learning in Maltese Schools

Scicluna (2020) emphasises that, given the tremendous changes that our society is undergoing, the Maltese educational system must be prepared to keep up with these developments. In their article, Camilleri and Camilleri (2017) note that, for children and

teenagers in general, in Malta, access to personal and wireless computers and equipment, including smartphones and tablets, has been on the increase for some time. The authors add that Maltese educators must adapt their teaching techniques to meet the changing requirements of students and the new realities of the classroom environment.

According to the Ministry for Education (2015) of Malta, digital literacy education empowers learners to utilise digital technology to obtain learning opportunities, find fulfilling employment and provide valuable contributions to society. Meanwhile, Said Pace (2020) observes that a deeper teaching and learning experience is generated by allowing frequent interactions to occur, such as, those between teachers and students and those between students. Indeed,

ICT can empower teachers and learners by shifting teaching and learning processes from being highly teacher-dominated to student-centred. This transformation will result in increased learning gains for students, creating and allowing for opportunities for learners to develop their creativity, problem-solving abilities, informational reasoning skills, communication skills, and other higher-order thinking skills (Gatt, 2015, p. 104).

Gatt (2015) notes that one of the objectives of the Directorate for Digital Literacy and Transversal Skills is the promotion of TEL as an effective learning tool to increase the possibility that students master fundamental literacy and numeracy skills. The author adds that, as the first concrete step towards integrating technologies in the classrooms, every teacher in Malta's public schools received a laptop computer. According to the author, this initiative developed further as teacher training was provided and the e-Learning Department was established within the Directorate for Quality and Standards in Education.

According to Malta's National Audit Office (2019), during the years 2016 and 2017, "tablets were distributed to all the Year 4 students, their educators, technical staff and support teachers, as well as peripatetic teachers, education officers and senior management teams in schools" (p. 20). According to NAO⁶ (2019), the tablets made educational materials more exciting and engaging, enabling educators to adopt another way to conduct continuous assessment without administering half yearly exams. One of the most prevalent uses of tablets of the One-Tablet-Per-Child project was found to be in the subject of mathematics, according to a survey completed by teachers (NAO, 2019).

Cutajar (2019) maintains that today's world requires innovators, and with robotics and programming education, students are provided with the logic and creativity they need to fulfill that role as technology opens new creative avenues hitherto inaccessible. She adds that it was observed that, when shy pupils were exposed to robotics, they seemed to gain confidence. According to the author, from an early age, there was evidence of collaboration and idea sharing as students assisted one another in completing assigned tasks. Nonetheless, Cutajar (2019) cautions that, reaching out to and engaging each student from an early age in activities involving computational thinking skills, logical reasoning, and problem-solving abilities does not guarantee that all students will flourish when using computers or in programming, however, problem solving becomes second nature to them as a result of their exposure to effective problem solutions in their daily lives.

The objectives of the research by Cutajar (2019) with some Maltese teachers and students were to determine how well an educational robotics project had succeeded, which included determining how effectively students gained skills in problem-solving,

⁶ NAO stands for National Audit Office.

computational thinking and logical thinking when they were taught using robots. According to the Cutajar (2019)'s research findings, robots acted as an effective and practical platform for instilling computational thinking processes, which "is a type of analytical thinking that shares many similarities with mathematical thinking (e.g., problem solving), engineering thinking (designing and evaluating processes), and scientific thinking (systematic analysis)" (Bers, 2010, p. 3).

According to the findings of the investigation by another two Maltese researchers, Lombardi Calleja and Trapani Maggi (2021), the employment of robots in mathematics meant that it no longer had to be a dreaded and unapproachable subject; rather, it became something where students could utilise their critical thinking and problem-solving abilities to understand better. From her part, Cutajar (2019) emphasises that "action needs to be taken in order to help students from a very young age to be better problem solvers and provide them with everyday situations to be better thinkers and learn how to work in groups" (p. 119). An initiative such as the EMBED project, where young pupils are taught how to programme using developmentally appropriate tools, enables students to increase their sequential abilities (Cutajar, 2019).

Spiteri and Chang Rundgren (2017) assert that it is necessary to incorporate digital competency education in teacher continuing professional development, and while participating in continuous professional development, teachers should be provided with opportunities to practise using technology while having the chance to give and receive feedback from one another. The authors add that teachers these days are becoming increasingly reliant on digital tools and should therefore be trained in how to identify

problem-solving options and how to use the latest teaching methodologies that include instantaneous feedback, peer feedback, and students' self-assessment.

Meanwhile, according to Scicluna (2020), technology must also be incorporated into the curriculum, concluding that the future of employment necessitates the development of skills for our younger generations in order to thrive in a rapidly changing digital economy. The author argues that it would be unfair to dismiss the fact that efforts have been made in the local community to equip Maltese State Primary schools with technological tools, but it is the responsibility of school administrators to ensure that the available digital tools are used to the greatest extent possible to benefit students.

Two projects, eTwinning and Erasmus, offer support for training teachers and provide funds to schools for more resources (Scicluna, 2020). Undoubtedly, resources including financial aid and technological capabilities are important, but, in reality, human resources are the most essential and teachers and students would both benefit from school leaders who nurture teamwork and lifelong learning (Scicluna, 2020).

The Government of Malta (1988) clearly states that the Directorate for Quality and Standards in Education is responsible for ensuring that information technology systems are accessible to everybody involved in the teaching and delivery of education in Malta and that they are used effectively. Additionally, every college should make sure that the National Curriculum Framework is tailored to the needs of pupils and all schools should employ innovative methodologies, including an extensive use of information and communication technology (Government of Malta, 1988).

2.6 The Bee-Bot as a Learning Tool in the Primary Classroom

As argued previously and as stated by Catlin and Blamires (2010), to be effective, educational robots must urge students to think, foster the development of new abilities, or provide them with hands-on experience, where they may apply what they have learned in the real world. The authors continue that robots assist pupils in problem-solving, sharing of knowledge, and building social skills.

As noted by Havlásková et al. (2019), the Bee-Bot is “a programmable robotic toy, an interactive digital tool for developing logical thinking, spatial imagination, planning and pre-mathematical concepts” (p. 202). Without a screen or display, the Bee-Bot requires some abstraction for children to know which commands are selected, thus being beneficial since it aids in the children's recall of their choices (Havlásková et al., 2019). Therefore, according to the authors, it is imperative to plan and keep in mind each command prior to implementation.

Meanwhile, Angeli and Valanides (2020) believe that children need an external memory system to facilitate their problem-solving tasks with the Bee-Bot since it helps with the cognitive demands imposed by sequencing tasks. The authors further suggest that, since the Bee-Bot is simple to operate, it is important for teachers to understand how to utilise it in pedagogical ways that are relevant to teaching children computational thinking to maximise its benefits.

Caballero-González , Muñoz-Repiso and García-Holgado's (2019) findings demonstrate that, as children were exposed to the basic concepts of sequential movements while building simple sequences using the Bee-Bot, they engaged their critical thinking skills and spatial perception abilities.

2.6.1 The Bee-Bot and Pupils' Computational Skills

Studies carried out in educational institutions have revealed that robots are particularly effective in improving students' abilities, while also making it fun to work with fractions, proportions, decimals and ratios, among other things (Gorakhnath & Padmanabhan, 2017). In the study by Baroutsis et al. (2019), a participant teacher who had implemented digital programming activities related to mathematics declared that “[t]he Bee-bots reinforced what they had learnt in the unit” (p. 14).

According to Bers, Flannery, Kazakoff and Sullivan (2014), when using robotics and participating in robotic activities, children actively participate in problem-solving and gain valuable knowledge, “including core concepts of computational thinking” (p. 156). The validity of this hypothesis was established by research findings that showed that children's computational thinking skills, statistically, improved considerably over time (Bers et al., 2014; González & Muñoz-Repiso, 2017; Bers, 2018; Baroutsis et al., 2019).

Wing (2008) suggests that, if we want a comprehensive and fundamental understanding of computational thinking to be applied to all aspects of our lives, the ideal time to learn computational thinking is in the early stages of life. For their part, Georgiou and Angeli (2019) discovered that, when using robots in classroom activities, those who are not visually perceptive need to use scaffolding to complete problem solving tasks and teachers should assess students' intellectual ability to determine that everyone is capable of learning with robots.

2.6.2 The Bee-Bot for Teaching Mathematics – Accommodating Different Learning Styles

According to Highfield and Mulligan (2008) and Highfield et al. (2008), there is little research on the potential beneficial effects of new technologies on children and mathematics education. In their study, Highfield et al. (2008) found that, while using the Bee-Bot, children were able to engage and demonstrate a grasp of geometric properties, the notion of positionality and directionality, measurement, estimation, counting, fraction concepts and partitioning while participating in the mathematics processing exercise.

The programming of robotic devices, such as the Bee-Bot, helps visually impaired students to learn the abilities to not only recognise and visually perceive shapes and textures, but also reason, compute, retain information and process spatial information and algorithms (Spinarova & Vachalova, 2021). Schina, Esteve-Gonzalez and Usart (2021) found that children with attention deficit disorder and dyslexia benefited greatly from the use of the Bee-Bot, which motivated them, enhanced their self-confidence, and provided them with a sense of accomplishment, while learners were taught time, numbers, and directions.

As Chaldi and Mantzanidou (2021) observe, some children on the autism spectrum are non-verbal and thus, need to be taught how to communicate via alternative and augmentative methods. They add that children on the spectrum may benefit greatly from educational robotics as a means of improving their communication abilities. Indeed, the Bee-Bot was shown to encourage greater interaction and engagement among pupils than traditional teaching approaches (Chaldi & Mantzanidou, 2021).

Lopez-Caudana et al. (2020) and Camilleri (2017) emphasise that, if teachers are well-prepared and familiar with the use of the robot, they would have the capacity to tailor learning techniques to their pupils' individual needs, while increasing the pupils' own responsibility for their learning.

2.6.3 Benefits and Weaknesses of Bee-Bot

The Bee-Bot's design is child-friendly, in the form of a black/yellow bee, and is simple to use and manipulate (Di Lieto, Inguaggiato, Castro, Cecchi, Cioni, Dell'Omo, Laschi, Pecini, Santerini, Sgandurra, & Dario, 2017). According to Highfield et al. (2008), the Bee-Bot can boost children's knowledge of mathematical concepts, particularly transformation and measurement techniques, far sooner than expected.

Meanwhile, Beraza et al. (2010) explain that children utilise the Bee-Bot's coloured buttons on its back to give it a series of simple motion or rotation orders. They add that lower-grade students may learn to solve topological difficulties, count and reason logically and discover inquiry-based methods of learning and teaching by using the Bee-Bot.

Students further investigate mathematical concepts such as counting and geometrical ideas by programming the Bee-Bot (Demo, 2008). Digital programming activities encourage students to actively participate, with no signs of disruptive behaviour (Baroutsis et al., 2019). According to Silk and Schunn's (2008) research, students become so immersed in robotics that they use their time and effort more efficiently to properly learn the mathematical concepts.

However, Beraza et al. (2010) observe that, while "the Bee-Bot robots are convenient to children in kindergarten and in early years of the primary school ... their programming power is very limited" (p. 554). Another concern of these authors is that of enabling children and teachers to create and implement tasks with Bee-Bot-like robots by providing computer support for such activities.

For their part, Georgiou and Angeli (2019) observe that a key drawback of the Bee-Bot's programming interface is the lack of a visible representation of the commands that

children input into it; thus, successful ways for scaffolding children's learning with the Bee-Bot are required.

2.7 Gender and TEL

Robotic kits are available in a variety of gender-neutral colours, and feature programming that is appropriate for children of all ages, including girls and boys, individuals of numerous cultural backgrounds, and people of many races (Mondada, Bonani, Riedo, Briod, Pereyre, Retornaz & Magnenat, 2017). Robotics in education could be considered as a tool that can assist in increasing the participation of girls in STEM⁷ disciplines, thus reducing unfavourable attitudes towards STEM disciplines that are formed at a young age that can be reinforced later in life (Weinberg, Pettibone, Thomas, Stephen & Stein, 2007).

The creation of an educational robotics environment that is gender diverse would ensure that both boys and girls have a positive learning experience and are motivated to continue learning (Yang, Liu & Chen, 2020). For their part, Castro, Cecchi, Valente, Buselli, Salvini and Dario (2018) found no significant variations in robotics knowledge between males and females following educational robotics tasks. Furthermore, Nugent, Barker, Grandgenett and Adamchuk (2010) assert that, although male students outperformed female students in both pre- and post-assessment, the average scores of males and females increased dramatically following robotics training.

According to Atmatzidou and Demetriadis (2016), computational thinking abilities would increase, regardless of gender, but it would take girls longer to obtain learning gains than boys. Gender differences in learning style preferences and the use of technology have

⁷ STEM stands for Science, Technology, Engineering and Maths.

been observed and documented (Dwyer, 1998). According to Gribbins, Hadidi, Urbaczewski and Vician (2007), females generally prefer group learning over individual work, and they enjoy learning in a social environment, while males tend to prefer independent learning scenarios.

Mann (1994), however, argues that girls are more likely than boys to face teacher prejudice. Voyles, Fossum and Haller (2008) found that girls and boys are unanimous in their common interest in computers and the process of creating things. They discovered the early signs of the often-reported boy-girl divide in attitudes only after examining the students' reasons for their preferences. According to the authors, by fourth grade, it is indicated that both boys and girls understand and implement gender stereotypes. Adya and Kaiser (2005) argue that gender stereotyping can become embedded in a girl's identity because of her exposure to it in society, as well as from her parents, teachers, and friends, amongst other influences.

In their article, Mauk, Willett and Coulter (2020) state that parents and caregivers bear the primary responsibility for exposing their children to coding and programming at an earlier age. The authors add that parents are being urged to "empower" their daughters to pursue careers in STEM subjects as part of the effort to encourage children to code.

Meanwhile, in their study, Denner, Werner and Ortiz (2012) found that middle school girls created computer games with the hope that the study would raise the students' interest in coding, improve their attitudes and discover the reasons behind any gender discrepancies.

According to Duncan, Bell and Tanimoto (2014), it is more likely that girls who have had prior programming experience in elementary school would be able to maintain their self-esteem and confidence in computing into their adolescent years. In addition, Angeli and

Valanides (2020) contend that the learning environment's design influences children's computational thinking task performance differently, depending on their gender. Therefore, creating a learning environment for boys and girls requires activities that are tailored to their specific developmental needs at each point of their development (Angeli & Valanides, 2020).

For their part, Yang et al. (2020) suggest that the best way to engage and interest more students in computer science and engineering may be to design technological activities that are both inclusive and appealing. Female students who are exposed to computer-related courses in early schooling are more likely to take computer science classes later in life. On the other hand, in the case of female students, a poor teacher may have an irreversible negative impact on their motivation to pursue a career in computer science (Fisher & Margolis, 2002).

Squicciarini , Borgonovi, Andrieu and Liebender (2019) believe that many measures might be adopted to reduce and eventually eliminate this gender disparity in educational institutions, such as, educators should be made more aware of their own unconscious gender prejudices and teaching resources should be gender-neutral. However, these efforts must be part of a broader strategy, while a high degree of commitment from policymakers and other collaborators is a requisite to succeed.

2.7.1 Gender Influence in Learning Through the Bee-Bot

Undoubtedly, schools play a critical role in bridging the gender digital divide by breaking down gender preconceptions that inhibit girls from gaining the skills, ambition, and self-assurance they need to succeed in the digital age (Squicciarini et al., 2019).

According to Angeli and Valanides (2020), a gender-inclusive robotics learning environment that encourages boys and girls to feel a sense of ease and enjoyment in their experience would help them both thrive and persist in their learning. The authors employed two scaffolding strategies to work on a task with the Bee-Bot. One of the techniques involved activities with cards that incorporated personal, tactile, spatially-oriented, and manipulative skills, while the other was a writing task that used a collaborative method.

The authors found that, while both genders profited from both strategies, boys gained more from the activity that focused on manipulating cards and developing kinesthetic, spatially-oriented and independent activities, while girls profited more from writing activities with collaboration. They could observe that, although both genders obtained learning gains from both scaffolding techniques, the design of the gender-inclusive learning environment had different effects on how well the kids did in computational thinking tasks.

Meanwhile, Papavlasopoulou, Sharma and Giannakos (2020) conducted a workshop involving an interactive robot and Scratch programming, whose objective, amongst others, was to help children, aged eight to seventeen years, perceive coding as something they can accomplish and that it is not a pursuit to be associated exclusively with boys. It transpired that, in the end, the children concluded that they felt capable of coding. However, the authors discovered that, regardless of both girls and boys claiming improvement in confidence and personal achievement, the girls possessed lower self-efficacy.

Urlings, Coppens and Borghans (2019) found that, when children's thinking time was measured, the outcomes of the Bee-Bot activities were identical for both boys and girls. Similarly, Papadakis and Kalogiannakis (2020) found no gender inequalities in early

computational thinking and coding in their investigation of Bee-Bot-enhanced activities with five- to six-year-old students. According to Yang et al. (2020), the growth of computational thinking learning in girls is slower than that in boys. However, they argue that robotic-assisted instruction, such as that provided by the Bee-Bot, may aid in closing the gender gap that exists between boys and girls, albeit concluding that it is still unclear whether gender has an impact on learning with the Bee-Bot, hence necessitating additional research.

The importance of dedicating attention to these early childhood years cannot be overstated as they lay the groundwork for developing an interest in programming that is not influenced by conventional assumptions about boys and girls (Manches & Plowman, 2017).

2.8 Assessing for Mathematics Learning Using the Bee-Bot

The Ministry for Education (2015) proposes that educators should regularly keep track of a learner's development by carrying out observations, interacting with learners, providing parent-guide support and giving an account of the achievements of learners.

According to Lopez-Caudana et al. (2020), “active learning with strategies for doing, reviewing, learning and applying can be of support to contribute with the construction of mathematical knowledge” (p. 2). Robotic devices, such as the Bee-Bot, encourage pupils to engage in inquiry-based learning by introducing new ideas (Beraza et al., 2010), although, as Lopez-Caudana et al. (2020) observe, without the correct method, robotic approaches would fail to yield notable learning gains.

Students approach robotics with a light-hearted attitude (Beraza et al., 2010). Di Lieto et al. (2017) explain that the design of the Bee-Bot was built with younger children in mind. Bee-Bot programming enables students to explore with mathematical principles while

they solve problems (Demo, 2008). Meanwhile, Highfield and Mulligan (2008) provide examples of CRiMSE⁸ design studies that examine how young children interact with technological tools and their influence on mathematics learning. The authors add that these design studies demonstrate that young children may be exposed to a wide range of advanced mathematical concepts while interacting with technology, such as, the Bee-Bot. Indeed, in their study, Ioannou et al.'s (2018) teachers acknowledged that, after using the Bee-Bot to teach road safety, they could immediately conceive of several math lessons that might be developed using the Bee-Bot.

Highfield (2010) contends that, thanks to robotic toys, educators of children in the Early Years are provided with impressive possibilities to blend mathematics practices with appealing problem-solving activities. The author further claims that robotic devices, such as the Bee-Bot, assist students in engaging with complex mathematical topics in a fun and prolonged manner and when mathematical practices offer more than one correct solution, this develops creativity and critical thinking, while engaging in critical reflection. According to Heikkilä and Mannila (2018), students' understanding of mathematical concepts such as forward, backward, right, and left can be improved as a result of the programming opportunities that are provided, such as, with the Bee-Bot, while enabling them to discover and recall patterns.

Meanwhile, González, Morales, Nielsen, Muñoz and Villarreal (2019) explain that mathematical learning entails complicated processes that need a wide range of techniques to reach optimal effectiveness. They further note that the application of ICT⁹ and

⁸ CRiMSE stands for Centre for Research in Mathematics and Science Education.

⁹ ICT stands for Information and Communications Technology.

educational robotics is particularly well adapted to this purpose, and with their help, a pupil can move forward swiftly while also better comprehending and remembering new knowledge that is encountered in the learning process. Kritzer and Green (2021) state that, by incorporating the latest technological advances into their lesson plans, educational materials, such as the Bee-Bot, allow teachers to better engage their students in coding activities that foster creativity and critical thinking skills. The authors note that early numeracy abilities like counting, addition, subtraction, and estimation can be explored using these tools in a hands-on way.

According to Highfield et al. (2008), the Bee-Bot's tactile manipulation and programming without needing a screen provide various solutions to problems, adding that each child goes through a different set of actions and reflections that culminate in their development of abstract thinking. For their part, Hoyles and Noss (2003) believe that, in mathematics education, these cognitive processes of problem solving and abstract thinking are essential to the development of a strong cognitive foundation.

2.9 Support and Limitations of Integrating Pedagogically the Bee-Bot

However, Catlin and Blamires (2010) and Camilleri (2019) caution that, for teachers to consider utilising robots, such as the Bee-Bot, they must believe that their actual value is more than the amount of time required to coordinate their preparation. According to Dalby and Swan (2019), it seems that a deeper understanding of how technology might support effective learning processes is still needed before further pedagogical reforms can be undertaken.

Beraza et al. (2010) explain that, to build and carry out activities involving Bee-Bot-like robots, students and teachers need computer assistance. The authors give an example

of a teacher who would need computer assistance, such as, “to register kid’s progresses, or to compare how their skills evolve on the same kind of problems” (p. 555). Meanwhile, Mubin, Stevens, Shahid, Al Mahmud and Dong (2013) argue that, to instruct students in the principles of robotics, the training of teachers on robotics and robotic curriculum design are critical. It is important that educational institutions include school leaders who can swiftly perceive the changing technological environment, who put forth feasible solutions and who exhibit perseverance and leadership in demonstrating these qualities (Camilleri, 2019; Scicluna, 2020).

Meanwhile, Savard and Freiman (2016) argue that, despite robotics being more popular to incorporate both elementary and secondary school children in a STEM curriculum, its impact on students' learning has not been investigated much. The authors add that, in the past few years, “where robotics captures the attention of STEM educators as a potentially rich and authentic context for introducing integrated curriculum in schools, especially at the elementary level, the issue of assessment remains unclear” (p. 111). For their part, Gorakhnath and Padmanabhan (2017) highlight that, even if robotics is not yet receiving as much importance in the school curriculum, the use of robotics continues to grow, with the participation of teachers, researchers, and students.

2.10 Conclusion

Given the growing importance of formative assessments, technological advancements stand to play an increasingly important role in this kind of assessment. Students benefit from technology because it offers scaffolding and reinforces their learning outside of the classroom. Robotics-based learning experiences are dynamic and effective because they include a variety of learning methods.

The Bee-Bot is effective in capturing the pupils' attention. With the inclusion of robots in the curriculum, a new approach to education may be developed. This would undoubtedly have a significant impact on the achievement of several academic disciplines' goals because robotics-based activities may provide a rich background for students to identify and research questions, while forming their own ideas and interpreting the results based on their findings.

Chapter 3

RESEARCH METHODOLOGY

3.1 Introduction

The aim of this qualitative study was to explore the educators' and the pupils' perspectives and interpretations of the Bee-Bot's use and efficacy in the assessment for learning of mathematics in Year One. An interpretivist constructivist grounded theory methodology was adopted. The design that was employed in this investigation is explained in this chapter. According to Charmaz (2006), “[g]rounded theory can give you flexible guidelines rather than rigid prescriptions ... [enabling you to direct a] ... study but let [the] imagination flow” (p. 15).

A grounded theory (henceforth GT) approach was adopted because it incorporates theory into the actual views of the participants (Charmaz, 1990). This chapter thus explains why a constructivist grounded theory methodology was utilised to gather and analyse data. It further offers a critical description of the epistemological and ontological ramifications of the constructivist paradigms, the research design, data collection, data analysis, and ethical issues.

The aim of this research was therefore directed to discover solutions to the following main research question:

- What are the perceptions of professional educators and pupils about the effectiveness of the Bee-Bot in the assessment for learning of mathematical concepts?

To approach this crucial question, the study needed to engage with two other subsidiary questions:

- In what way is the Bee-Bot enhancing the teaching and learning process?
- What are the pedagogical advantages and disadvantages of the Bee-Bot?

As suggested by Charmaz (2006), school children and professionals were interviewed in order to collect empirically rich information. Grounded Theory methods such as continuous constant comparison, coding and memoing were subsequently utilised for data analysis. By critically reflecting on *a priori* assumptions, the grounded theory technique assisted this researcher in identifying and monitoring her biases (Birks et al., 2019).

3.1.1 A Qualitative Approach

For this investigation and in accordance with the principles of constructivist grounded theory (Charmaz, 2006), this research utilised Grounded Theory data gathering tools with qualitative data collection and analytic approaches. According to Baker (2000), qualitative research has demonstrated a number of unique scenarios in which it is especially valuable, such as, the initial investigation and organising and classifying concepts. The author adds that it is beneficial to foster a better understanding of human behaviours, while allowing the decision maker to get a first-hand impression of how participants perceive the world thereby identifying the needs and abilities that have yet to be met.

While conducting qualitative research, this researcher was aware that several realities exist concurrently; therefore, she undertook an investigation with the aim of presenting several individual realities (Creswell, 2007). A qualitative methodology was adopted for this study since, as Greenhalgh (2002) explains, in qualitative inquiry, interpretations of social phenomena are socially constructed and the purpose of this research was to understand the phenomenon via the participants' diverse points of view.

Denzin and Lincoln (2018) describe qualitative research as involving three generic tasks, all of which link to one another, namely, ontology, epistemology, and methodology. This researcher explored the participants' viewpoints with a framework of ideas (ontology) and questions in mind (epistemology) and she conducted research to learn more about these concepts and issues (methodology) (Mills, Bonner & Francis, 2006).

3.2 The Research Paradigm

A paradigm represents a group's unified set of beliefs or worldview (Donmoyer, 2006). Pre-defined conceptual frameworks that embody the constructivist qualitative research paradigm served as a framework within which this researcher could conduct her investigations, while also bearing in mind that paradigms are tools for exploration, not an alternative to knowledge (Hartas, 2010). This researcher was aware that the qualitative paradigm is based on the idea that the world is made up of a variety of constantly changing realities (Merriam, 2009).

Wilson (2017) believes that "the adoption of a paradigm is principled. It relates to fundamental notions about the nature of: (a) what is being researched; and (b) the knowledge that may be produced in the research" (p. 324). Considering that qualitative research is founded on diverse conceptions of reality, this researcher trusts that the validity and reliability of her findings would be seen through the prism of the philosophical assumptions that support a constructivist research paradigm (Merriam, 2009). This researcher adopted a constructivist philosophical paradigm since she was interested in how humans are creators of their own understanding and knowledge of the world through their experiences and reflections on them (Honebein, 1996).

3.2.1 Epistemological and Ontological Underpinnings of the Study

Hitchcock and Hughes (1995) note that “[i]t is fair to say that the basic ontological and epistemological assumptions held by any researcher will shape the kind of methodology which those researchers will adopt” (p. 15).

Meanwhile, for Crotty (1998), epistemology is the understanding and description of how we come to know things and ontology is the branch of philosophy concerned with what it means to be, hence what exists or the essence of reality itself. As this researcher’s views on reality shape her philosophical attitude, the version of Grounded Theory she chose to follow was inextricably bound with her ontology and epistemology (Birks et al., 2019). This researcher’s ontological and epistemological views determined where she began in a cycle of methodological growth, with various places of initiation along the way (Mills et al., 2006).

As suggested by Birks and Mills (2015), this researcher recognised that it was necessary to reflect on her own philosophical perspective to comprehend her own ideas about reality and how she came to perceive it. Once she decided where she stood on the issue of ontological validity, it was time to consider her perspectives on how she was to obtain valid knowledge. The choices and decisions made by this researcher on how to get accurate knowledge were also influenced by her philosophical beliefs about reality.

Scotland (2012) argues that “[r]esearchers need to take a position regarding their perceptions of how things really are and how things really work” (p. 9). First, this researcher's ontological and epistemological stance was established, allowing her to select a point on the methodological spiral of grounded theory, where she felt conceptually comfortable, subsequently allowing her to live out her views during this investigation (Mills

et al., 2006). This researcher sought to improve the quality of this qualitative research and foster credibility by adopting a reflexive stance (Patton, 1999).

According to Schwandt (2001), reflexivity is utilised methodologically “to refer to the process of critical self-reflection on one's biases, theoretical predispositions, preferences, and so forth” (p. 224). As suggested by this author, this self-examination was useful for this research and demonstrated that this researcher is a participant in the environment and social phenomenon that she attempted to comprehend. According to this notion of reflexivity, it is a necessary step in determining whether explanations for social phenomena are feasible.

The use of the constructivist grounded theory as a research technique was considered the most valid and compatible with this researcher's position, both ontologically and epistemologically. This study thus employed Charmaz's constructivist grounded theory. Making meaning of the world was achieved through this researcher's theoretical perspective, which is a component of her epistemology (Crotty, 1998). “Ontologically relativist and epistemologically subjectivist, constructivist grounded theory” (Mills et al., 2006, p. 9) complemented this study's paradigmatic position since epistemological subjectivism states that “meaning does not come out of an interplay between subject and object but is imposed on the object by the subject” (Crotty, 1998, p. 9) and the ontological viewpoint taken by interpretivism is one of relativism (Guba & Lincoln, 1994).

Meanwhile, Bodner (1986) observes that, according to realists, everyone's view on reality is unique to them. This researcher was reflective by considering who she was as a researcher and how she arrived at her research conclusions. Therefore, through reflexivity, this researcher was able to be open about her research choices (Engward & Davis, 2015). By

making use of reflexivity, this qualitative researcher could explore “[her] own stance, [her] values, [her] role in the research process, so that any potential for bias or prejudice is stated explicitly” (Engward & Davis, 2015, p. 1535).

3.2.2 Constructivism

Constructivists believe that what learners learn is shaped by what they already know and have gone through as they are learning (Mubin et al., 2013). A constructivist model of knowledge was adopted for this research as an approach for addressing the fundamental epistemological question on how we came to have the knowledge that we have of the world (Crotty, 1998).

This researcher believes that knowledge is created in the mind of those who learn it (Honebein, 1996). Piaget looked into how children learn, becoming the first constructivist to argue that knowledge is generated in the mind of the learner (Bodner, 1986). Meanwhile, Cobern (1993, p. 109) notes:

The definition of constructivism is carried in its name. Learning is the active process of constructing a conceptual framework. The philosophical basis for constructivism is epistemological fallibilism. All knowledge is fallible by virtue of lacking exactitude and comprehensiveness. Ultimately, we can never know for sure how close our knowledge actually approximates reality. Rather, knowledge is a meaningful interpretation of our experiences of reality.

“Constructivists study how - and sometimes why - participants construct meanings and actions in specific situations” (Charmaz, 2006, p. 130). By investigating constructively the perspectives of the participants on how the Bee-Bot can be utilised for the assessment

for learning of mathematics, this researcher discovered how the participants constructed their knowledge around their experiences.

Cobern (1993) asserts that, according to the learner's constructivist model, learning is constantly impacted by past knowledge; therefore, the teacher and student must come to an understanding before moving further. The author adds that this tells us that learning entails compromise and interpretation, and thus, teachers should encourage their pupils to engage in conversation that supports compromise and interpretation activities. This researcher, like Charmaz (2006), believes that facts and values are intertwined, and she is aware that perceptions are shaped by values.

According to Bodner (1986), a constructivist perspective maintains that our brains are made up of both the data we get from our senses and the cognitive frameworks we employ to make sense of it. The author believes that the construction of knowledge is a process wherein information is created and is then constantly put to the test. This researcher was interested in a theory of learning that focuses on the construction of new knowledge and where students are regarded as active participants in the process of learning rather than passive recipients of information (Cobern, 1993).

This researcher was interested in Cobern's (1993) statement that learning occurs through the process of interpretation. Indeed, Cobern (1993) notes that prior information always influences the interpretation and the use of discourse facilitates this interpretation. This researcher was fully aware of this fact. Cobern (1993) further asserts that, when inquiry activities serve as a platform for discourse, the value of the activities is enhanced. Bodner (1986) explains that, as a result, the constructivist approach necessitates a little adjustment

in the teacher's viewpoint. Therefore, as suggested by this author, this researcher looked at how the teacher seeks to encourage learning by negotiating knowledge with the students.

“Constructivism is not just a theory of learning; it is a theory of knowledge” (Confrey, 1998, p. 106). Following the author's view, this researcher was conscious of how knowledge is not simply a collection of unchanging facts, but it performs an adaptive purpose. During their interactions with this researcher, the pupils revealed the knowledge structures they had constructed as a result of their time spent engaging and learning with the Bee-Bot.

3.2.3 Choice of Research Strategy

As suggested by Corbin and Strauss (2008), it was important for this researcher to engage in extensive reading on the subject matter she planned to investigate. It was critical for this researcher to recognise what other researchers have discovered about comparable or related issues, what ideas have been advanced and where knowledge gaps are.

Meanwhile, following Kumar (2011), prior to devising a research strategy, this researcher first identified a research problem. Identifying potential difficulties assisted her in selecting a research strategy that yielded trustworthy results for her research question(s). The recognition of potential issues also enhanced this researcher's trust in the technique she wanted to employ, and it prepared her to defend her decision to utilise the constructivist grounded theory methodology. According to Grinnell (1993), research is a systematic investigation and this researcher utilised established scientific techniques to address challenges, generating new information that could be applied in a broad range of circumstances. Figure 3.1 depicts the development and application of the Constructivist Grounded Theory methodology for this study.

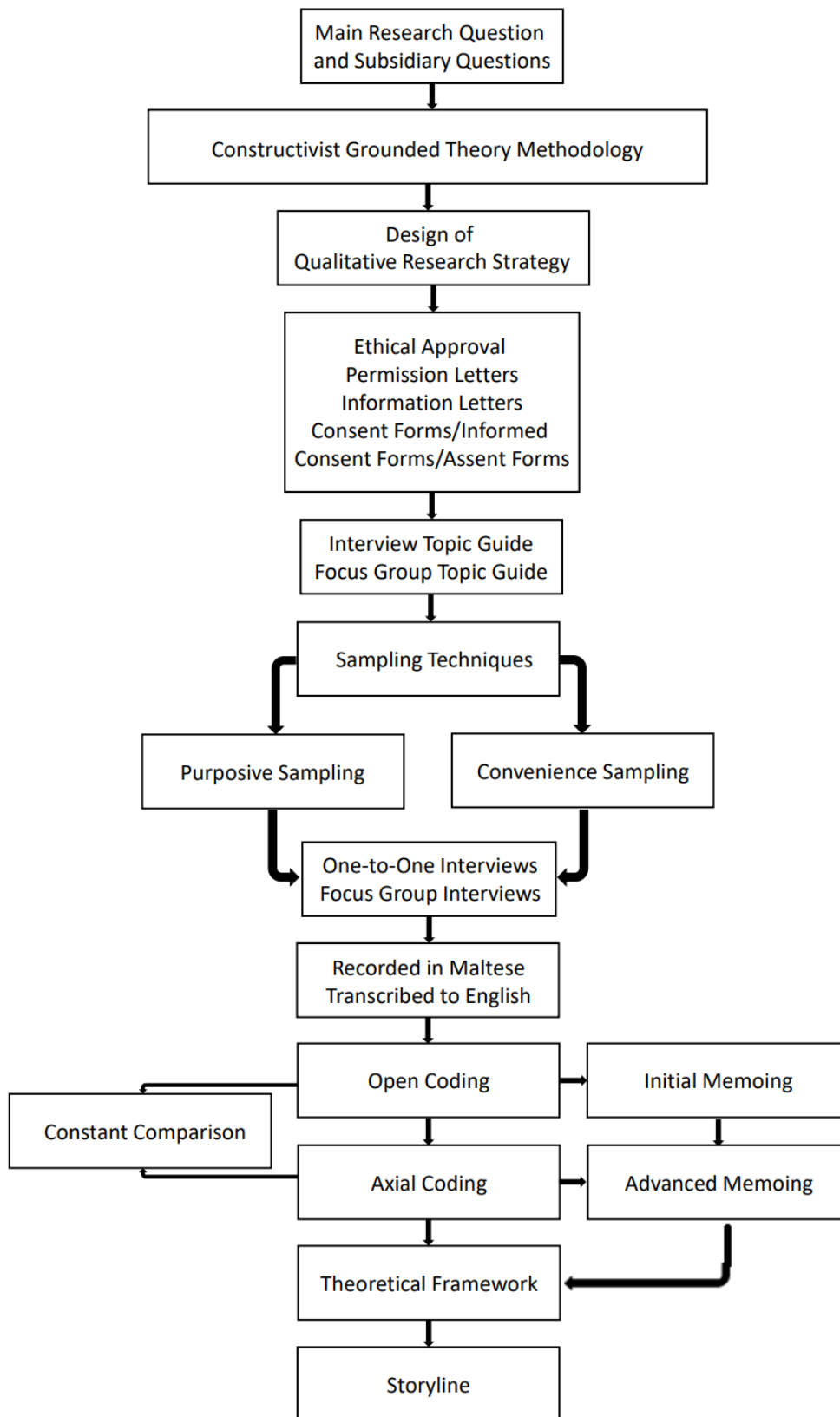


Figure 3.1: Constructivist Grounded Theory methodology used in this scientific investigation.

Based on their studies of people dying in hospitals in the 1960s, two American sociologists, Glaser and Strauss, developed grounded theory (Glaser & Strauss, 1965). Glaser and Strauss both aspired to discover more regarding people and their actions (Bluff, 2005). Due to the absence of prior knowledge or theory in Maltese research literature on the utilisation of the Bee-Bot to assess for learning of mathematics, grounded theory can be a useful creative technique to employ, as Glaser & Strauss (2017) suggest, although developing their methodology in the US. This researcher thus employed grounded theory since it is a technique for generating new ideas that may be used to improve current theories (Bluff, 2005).

Researchers from a wide range of disciplines can use grounded theory to investigate unusual events, utilising a myriad of data sources (Birks et al., 2019). To arrive at a theoretical explanation, this researcher employed a grounded theory inductive approach to reasoning (Strauss, 1987), aiming to make use of data that provided more than a simple description, which is what distinguishes grounded theory from other research methods (Birks & Mills, 2015). This researcher conducted early analytic writing since it is an important part of grounded theory methods, that encouraged this researcher to view the data in novel ways and investigate her perspectives on the data (Charmaz, 2006).

This researcher used the constant comparative approach, which necessitated comparisons at every level of the study (Glaser & Strauss, 2017; Strauss, 1987). The outcomes of this grounded theory technique contributed to current knowledge and to new theoretical insights (Strauss, 1987). Following Charmaz (2006), this researcher had an obligation to reflect on what she contributed to the situation. Her reflexivity technique was consistent and ongoing throughout the study (Vancell, 2018).

By using grounded theory, this researcher could delve into occurrences that had been looked at by others, albeit not by the discipline in question (Stern, 1980). This researcher was interested to know how, through previous and present participation and connections with other individuals, viewpoints and study techniques, researchers build foundational ideas (Charmaz, 2006). Birks et al. (2019) explain that the development of theory, that is based on empirical evidence, is a significant aspect of grounded theory.

Meanwhile, Birks et al. (2009) note that it is possible to better depict a theory's dynamic character and strengthen its explanatory power by using the storyline as the foundation for illustration design. As recommended by these authors, storyline assisted this researcher in building an integrated concept by offering a technique that allows for comprehensive synthesis and abstraction of data. Due to the nature of storyline, this researcher, following the advice of Birks and Mills (2015), sought to dissociate temporarily from the data in order to engage in significant abstract thinking.

As suggested by Engward and Davis (2015), by using grounded theory, this researcher had the opportunity to delve deeper into certain elements of social phenomena that proved crucial to the participants' understanding. Therefore, this researcher examined with great care the accounts of the participants in order to identify patterns, contradictions, and discrepancies among them. According to Engward and Davis (2015), in grounded theory, this is essential to the conceptual framework since it moves the study away from anecdotal accounts and towards explanations of what happens in the data.

3.2.4 Constructivist Grounded Theory Methodology

According to Piaget (1972), learning is not an inert process of receiving knowledge; instead, it is an active process of creating new knowledge based on prior knowledge and experiences obtained in the actual world. By focusing on the phenomenon under research, constructivism sees data and analysis as the consequence of relationships and shared experiences with participants and with other information sources (Charmaz, 1990) since constructivism is rooted in interpretative traditions (Charmaz, 2006).

The purpose of this study was to put maximum weight on the participants' perceptions. Rather than attempting to organise the participants' experiences into a restricted number of categories or concepts, this researcher sought perspectives that were diverse and intricate in their expression (Creswell, 2007). Following Mills et al. (2006), the participants' data and this researcher's interpretations of that data were used in conjunction with the constructivist grounded theory to create a sound theoretical framework for this study.

Constructivist grounded theory has its foundations in relativism and an appreciation of the multiple truths and realities of subjectivism. Undertaking a constructivist enquiry requires the adoption of a position of mutuality between researcher and participant in the research process, which necessitates a rethinking of the grounded theorist's traditional role of objective observer (Mills et al., 2006, p. 8).

As recommended by Mills et al. (2006), building upon constructivism's ontological relativism and subjectivism, constructivism redefines the researcher-participant interaction. Therefore, this researcher adopted the position of an author, putting her contributions at the front and central to the research methodology. Through the use of a constructivist

grounded theory approach, this researcher succeeded in delving into tacit meanings and processes, while remaining cognizant of overt dynamics (Ng, 2011).

Charmaz, Thornberg and Keane (2018) explain that the constructivist grounded theory holds that individuals create the phenomenon being researched and the research process by the actions they undertake. The construction of meaning of this investigation led to a storyline built on the participants' and the researcher's experiences as "an accurate reflection of the data within which it is grounded" (Birks et al., 2009, p. 407).

For her constructivist research, this researcher placed a strong emphasis on and assessed the relationship that existed between the participants and herself, as recommended by Mills et al. (2006). This researcher was aware that a constructivist approach necessitates the development of connections with participants; thus, she sought to identify and address any power inequalities (Mills et al., 2006). She also sought to avoid assigning a value to the participants' replies or even to the participants themselves, while being aware of maintaining a non-judgemental stance towards them (Holloway & Fulbrook, 2001).

As recommended by O'Connor (2001), to give the participants greater control over the course of the conversation, this researcher used a semi-structured and reasonably flexible approach thereby enabling the participants to assume more authority over the dialogue. This researcher also shared her knowledge of the major problems surfacing and assumed an open posture towards the participants, while answering questions during and after the interview.

This researcher's unique position, subjectivity, and contextual knowledge are emphasised by constructivist grounded theory (Charmaz et al., 2018). This researcher

concentrated on how experiences are constructed, as well as the meanings that are buried within them and on the conditions and situations that lead to them (Wertz, Charmaz, McMullen, Josselson, Anderson & McSpadden, 2011). During this research, the yielded data was a product of the researcher and the subject being studied working together to create it (Charmaz, 2011). The study's findings are shaped by the assumptions, circumstances, and preconceptions that went into its development.

The constructivist grounded theory begins with an inference and progresses through the stages of interpretation and comparison to arrive at a final theory (Wertz et al., 2011). This researcher believes that the constructivist grounded theory technique was highly helpful when analysing the participants' perspectives on the use of the Bee-Bot for mathematics learning.

3.3 Data Collection Methods

When conducting research to build a theory based on evidence, this researcher thought it essential to pay attention to both the data itself and the procedures that were utilised to obtain or gather the information (Birks & Mills, 2015). This researcher gathered information from a number of sources in order to obtain a more complete picture, collecting thorough information about the participants' views and behaviours, gathering data that goes beyond the surface level and into the depths of the subject matter and in a way that considers both the comparative and categorical value of the data (Charmaz, 2014). Indeed, each research project has the problem of ensuring the best possible quality (Bryman, 2016).

According to Merriam (2009), the researcher is the most important tool for gathering and analysing data. This researcher followed the author's recommendation and remained

aware of her capacity to quickly adapt and respond to changes in her environment, albeit being highly attentive to her own flaws and prejudices that might skew the results. Prior to beginning her research, this researcher made a list of any biases she was concerned would affect the quality of her findings. She was conscious of the possibility that her preconceived notions and biases about the phenomenon at hand may cloud her judgment and prevent her from seeing it in an unbiased light (Birks & Mills, 2015).

Following Merriam (2009), instead of trying to eradicate these biases, this researcher made sure to recognise them and keep track of how they influenced the way data was collected and interpreted. Since the data must support any interpretation, this researcher was compelled to confront continuously her own biases and beliefs in the face of the evidence (Bogdan & Biklen, 2007).

The validity of this research stems from the fact that the emerging theory is consistent theoretically, that its empirical interpretations are accurate, and that it is well-grounded empirically and conceptually (Bryant & Charmaz, 2007).

3.3.1 Sampling Techniques

As suggested by Miles, Huberman and Saldaña (2014), when conducting sampling, this researcher kept in mind that sampling entails making decisions not just about people to interview but also about circumstances, occurrences, and social processes. With the help of a conceptual framework and the research questions, it was possible for this researcher to determine the scope and limitations of sample decisions.

Hartas (2010) explains that convenience sampling and purposive sampling are two non-probabilistic sampling techniques that are widely employed in educational research.

This researcher utilised purposeful sampling to recruit a varied group of experts in the field (Denzin & Lincoln, 2018; Wilson, 2017). As proposed by Creswell (2012), she employed purposive sampling to select individuals who were especially useful in comprehending the phenomenon under investigation, thus offering in-depth knowledge.

The participants were chosen through purposive sampling based on their potential to contribute important information, aid in the understanding of the phenomenon, and provide a voice to other people. This researcher chose a sampling technique that could guarantee the recruitment of a wide range of individuals with different characteristics relevant to the study's research topic (Bryman, 2016). Despite this, since purposive sampling is a non-probability sampling strategy, this researcher was unable to generalise her findings to a larger population in this research (Bryman, 2016; Hartas, 2010). As Hartas (2010) recommends, this researcher recruited a small number of participants to obtain comprehensive and contextualised information about the focus of this research. Indeed, “we should be realistic about the number of participants we can access and the nature of the information we can obtain from them” (Hartas, 2010, p. 71).

Since it is a quick and straightforward approach to choose participants based on availability and willingness to participate, convenience sampling was utilised for the children participating in this research (Hartas, 2010; Wilson, 2017; Hesse-Biber & Leavy, 2006). The children attended the same Primary school and were in the same Year level. Leavy (2017) states that it is a common strategy to utilise convenience sampling when a researcher has access to participants just at a certain location.

3.3.2 One-to-One Interviews

According to Charmaz (2006), intensive qualitative interviewing lends itself particularly well to grounded theory approaches, adding that, since intensive interviewing allows for an in-depth study of the topic, it is therefore an effective approach for interpretative investigation. For the purpose of this research, intensive interviewing was open-ended, uncontrolled, and paced, but also guided, organised, and shaped. With the help of this researcher's interview questions, the interview was akin a dialogue with a specific goal in mind (Lofland & Lofland, 1995), where the participants were requested to explain and reflect on their experiences in ways that are uncommon in ordinary situations (Charmaz, 2006).

Since interviews are a form of conversation between the researcher and the respondent (Mishler, 1986), this researcher began the interviews with unstructured questions to enable the interviewees to talk without interruption, while the researcher indicated that the interview would be recorded (Corbin & Strauss, 2008). Since interviews are shaped by the meaning respondents ascribe to the things they say in response to the interviewer's inquiries, this allowed this researcher to get a clear image of the respondents' worlds of meaning (Mishler, 1986), which are "adequate to the tasks of systematic analysis and theoretical interpretation" (Mishler, 1986, p. 7).

3.3.2.1 Recruiting Participants and Conducting Interviews

According to Charmaz (2006), grounded-theory based methods offer systematic recommendations for digging deeper and examining the context. As Charmaz (2006) states, "[a] study based upon rich, substantial, and relevant data stands out" (p. 18). Charmaz (2006) recommends the researcher to plan to collect sufficient data to suit his/her task, to

provide him/her with a complete picture of the topic within the parameters of his/her project, regardless of the methods s/he chooses. Through in-depth interviews, the interviewer elicits vivid descriptions and insightful reflections from the interviewee. The role of the interviewer is to attentively listen and encourage the interviewee to express their feelings and thoughts. As a direct result of this, this participant dominates the conversation (Charmaz, 2006).

Charmaz (2006) states that the reliability and validity of the findings are dependent on the quality of the data. A study stands out when it is filled with rich, meaningful, and relevant data. Since intensive interviews are an effective tool, they allowed this researcher to conduct in-depth investigation into the topic by probing “further and asked more questions” (Charmaz, 2006, p. 35). According to Charmaz (2006), “[b]y creating open-ended, non-judgmental questions, you encourage unanticipated statements and stories to emerge” (p. 26).

The researcher aimed to conduct in-depth interviews with people who have first-hand knowledge of the situation under investigation, who are comfortable talking about it and when there are divergent viewpoints, they could be reliably selected to represent that range of viewpoints (Rubin & Rubin, 1995). Education professionals were recruited to participate in this study because the researcher was interested in learning their thoughts on the use and effectiveness of the Bee-Bot for assessing students’ acquisition of mathematical concepts. Furthermore, this researcher interviewed Year One pupils since she was also curious about their perspectives on the use of the Bee-Bot for mathematics learning.

The researcher recruited participants by first securing permission from the Ministry for Education and the Head of School where teachers were to be selected for the study.

Subsequently, the participants received emails or hand-delivered information letters (see Appendices 8 and 9) and consent forms (see Appendices 10 and 11). Since some participants were young learners, parents or guardians were given informed consent forms (see Appendices 12 and 13), and students were given assent forms (see Appendices 14 and 15). This researcher, who is also a teacher at the school, personally handed the information letters and consent forms to the Head of School and to the teachers.

Informed consent was employed in this study to make sure all participants included knew their rights and knew what they could expect. In order for the research participants in the study to make a well-informed decision regarding consent, they were given details concerning the anonymisation process. The researcher employed pseudonyms, the most frequently used way of protecting the privacy of research subjects (Bager-Charleson & McBeath, 2020).

The interviewee's comfort level was taken into consideration when selecting the environment as some situations may be better conducive to a discussion than others (Hartas, 2010). During the research, this researcher had a clear understanding of what she expected to gather from the interviews (Wilson, 2017). It was necessary to inquire about certain areas as research focus so as to respond to this study's research questions from the perspective of the interviewees (Bryman, 2016). When conducting the interviews, this researcher's goal was to learn as much as possible about the respondent's views on the subject, knowledge that the respondent was willing to provide and enlarge on in the right circumstances and with the right procedures (Gubrium & Holstein, 2001).

According to Charmaz (2006), qualitative research is flexible, so new leads can be followed. The grounded theory approaches enhance this flexibility and lend a stronger focus

than alternative approaches. The process of establishing a clear focus on what is going on in your data is accelerated with grounded theory. As Charmaz (2006) states, “[l]ike a camera with many lenses, first you view a broad sweep of the landscape. Subsequently, you change your lens several times to bring scenes closer and closer into view” (p. 14).

Since this investigation employed a grounded theory approach, this researcher sought to “devise a few broad, open-ended questions” (Charmaz, 2006, p. 26) (see Appendices 16-19). Then, as Charmaz (2006) advises, this researcher narrowed down the interview questions for a more in-depth discussion of the topic. With the use of open-ended, non-judgmental inquiries, it was easier to elicit unexpected answers and stories. This researcher sought to develop the questions well and conduct the interview successfully by attempting to “achieve a balance between making the interview open-ended and focusing on significant statements” (Charmaz, 2006, p. 26). This researcher further sought to maintain objectivity at all times during the conversation (Gubrium & Holstein, 2001). “Ideally, the interviewer uses his or her interpersonal skills merely to encourage the expression of, but not to help construct, the attitudes, sentiments, and information in question” (Gubrium & Holstein, 2001, p. 14).

Charmaz (2006) states that reflexivity is crucial in grounded theory methodology because it allows the reader to evaluate the extent to which the researcher's interests, positions, and assumptions influenced the inquiry by providing insight into the researcher's reflections on his or her own research experience, decisions, and interpretations. Bryant and Charmaz (2007, p. 479) state:

A researcher's self-awareness, knowledge of the subject under investigation, and skills to discern and be sensitive to salient but subtle aspects of the data are vital for qualitative inquiry, especially grounded theory.

During the interviews, attention was given to both the clear descriptions and meanings, as well as what was stated indirectly, as suggested by Kvale (1996). Furthermore, more information was sought from research participants due to the need to learn more about areas that appear to be particularly analytically important. Indeed, during the interviews, the participants were urged to elaborate and expand on the perspectives they were expressing, utilising verbal and nonverbal tactics in a non-directive manner (Hartas, 2010). As the interviews progressed, the researcher sought clarification on some points to collect reliable data and learn about each research participant's thoughts and feelings (Charmaz, 2006).

For the purpose of this research, the questions and order of the interview were laid out in an interview guide (Kvale, 1996). A topic guide was used for the interviews, rather than planned questions; thus, knowledge was constructed, instead of revealed (Vancell, 2018). The topic guide consisted of a few general ideas of what needed to be covered and a series of specific questions with precise wording (Kvale, 1996), such as, 'How do you think the Bee-Bot is effective in assessing the learning of mathematics?' and 'How can teachers assess mathematical measurements using the Bee-Bot?'. While conducting the interviews, this researcher kept in mind that less structure was preferable in order to follow the flow of the discussion (Gubrium & Holstein, 2001).

This researcher included the conversation between the interviewer and interviewee in the interview transcriptions that were subsequently utilised in her analysis and

interpretation (Mishler, 1986). Meanwhile, as soon as the interviews were completed, they were transcribed verbatim by the researcher and thereafter analysed as the method of grounded theory demands the synchronisation of concurrent data collection and coding processes thereby enabling a systematic approach, while allowing emerging topics to be explored in the following interviews (Engward & Davis, 2015).

3.3.3 Focus Groups

Focus groups emerged in the late 1930s as a result of a lack of other options for interviewing (Krueger & Casey, 2000). Meanwhile, Bryman (2016, p. 501) explains:

The focus group practitioner is invariably interested in the ways in which individuals discuss a certain issue as members of a group, rather than simply as individuals. In other words, with a focus group the researcher will be interested in such things as how people respond to each other's views and build up a view out of the interaction that takes place within the group.

Focus groups in this research project served to illuminate a wide range of pupils' viewpoints (Wilson, 2017). During the focus group interviews, attention was narrowed to a specific question and the participants were encouraged to engage in an in-depth discussion of that question among themselves (Hartas, 2010), such as, 'Can you describe the Bee-Bot to me?'. During the focus group interviews, this researcher did not merely listen to what the participants were saying, but also paid attention to how they were saying it (Bryman, 2016), thereby learning more about the dynamics of the group and disclosed issues that would otherwise be overlooked in a one-to-one interview (Laverty, 2016).

This researcher used focus group interviews as they are useful for stimulating discussion because participants react to and build off of one another. Useful information is gathered from the participants' interactions with one another. The goal of the focus groups was to gather further information. A comparison was made between data sets. Keeping the theory grounded in the data as it evolved made this an essential component of understanding (Birks & Mills, 2015).

This researcher, who was acting as the moderator during the focus group interviews, refrained from expressing personal viewpoints, approval, or disapproval and from interrupting the conversation (Kandola, 2012). However, when compared to one-to-one interviews, controlling group conversations is more difficult for researchers (Hartas, 2010). This researcher was thus cautious to remember the participants' names so that she would not have a hard time distinguishing between the members of the various groups (Wilson, 2017) when transcribing.

3.3.3.1 Determining Focus Group Participants and Conducting Focus Group Interviews

For this research, the focus group participants were chosen through convenience sampling. Focus group interviews were held in the students' actual school and during school hours, to ensure maximum participation. For the purpose of this research, small focus group interviews were employed since they allow for the exchange of different points of view, allowing the interviewer to follow up on leads provided by an individual's comments (Wilson, 2017). While the moderator guided the focus group sessions, she was extremely mindful not to be too intrusive in the sessions (Bryman, 2016).

As proposed by Bryman (2016), to get things started, the moderator greeted the students upon arriving and introduced herself. She then defined the research's goals and drew out the session's structure. Each focus group session was guided by a topic guide developed in accordance with the study's goals (Nyumba, Wilson, Derrick & Mukherjee, 2018). "In group settings, some may be less inclined to be open and honest" (Laverty, 2016, p. 12). Therefore, the group members were reminded that they were safe to express themselves freely since they would not be judged (Ritchie & Lewis, 2003). The interviewees were made to feel not just valued, but also essential to the success of the interview (Gizir, 2007).

Krueger (1994) outlines five types of questions, namely, the opening, introductory, transition, key, and ending. During this research, these were utilised consecutively throughout the focus group interviews. As suggested by Krueger (1994), this researcher, while acting as the moderator, was careful about the extent of her engagement or involvement at different stages of the focus group interviews. Meanwhile, in order to keep things in perspective, the moderator maintained a sense of proportion to the situation. Additionally, the focus group interviews were audio-recorded. This researcher was looking at how much and how strongly the interviewees agreed or disagreed on particular points of view (Morgan, 1996).

Since existing knowledge was insufficient and new hypotheses needed to be developed, the focus group interviews were beneficial (Powell, Single & Lloyd, 1996). The focus group's dynamic structure in this study allowed the participants to elaborate on their input to the conversation in light of ideas presented by other participants (Powell & Single, 1996). Due to their previous experience with and knowledge of the Bee-Bot, the focus group

participants were able to provide the information that was required (Gundumogula, 2020). It is beneficial when a participant is at ease when conversing with other participants (Morgan, 1988). Consequently, the participants in this study's focus groups were chosen from the same classroom to ensure that they were already familiar with one another.

Nonetheless, focus groups, like all other methods, have their own drawbacks. According to Gundumogula (2020), there is some risk of bias and manipulation due to individuals who take the lead, and it can be difficult to distinguish between an individual's view and the view of the group, making it difficult to extrapolate results from a small focus group to a wider community.

3.4 Constructivist Grounded Theory Analysis

Theory construction is the goal of grounded theory (Charmaz, 2017). For Charmaz (2006), "data form the foundation of our theory and our analysis of these data generates the concepts we construct" (p. 2). As recommended by Wilson (2017) and Hartas (2010), during this research, data analysis began immediately when it was gathered and the results were used to guide future data collection efforts. Early data analysis concepts offered what to look for and what to investigate next.

As suggested by Charmaz (2006), this researcher kept going back to the data and analysing it. Afterwards, this researcher returned to the research site to acquire additional data and strengthen the theoretical framework that was developing. The interviews were promptly followed by transcription. The first set of transcriptions were read by this researcher without any thought to interpretation. She then re-read the data, this time making marginal notes or remarks about noteworthy findings (Bryman, 2016).

3.4.1 Inductive Analysis

Wilson (2017) notes that inductive analysis is the discovery “of themes inductively through a constant comparison of data and building theory using a grounded theory approach to analyse data” (p. 253).

Grounded Theory research consequently employs a strategy that encourages the inductive development of new ideas, followed by a series of tests to make sure they hold up to scrutiny (Wilson, 2017; Wertz et al., 2011). In this research, each data unit was coded and then categorised (Charmaz, 2006; Creswell, 2012). Theoretical induction was accomplished by making consecutive comparisons (Birks & Mills, 2015). Using an inductive technique, this researcher looked at the data with a completely open mind and used themes that emerged from the data as analytical tools (Wilson, 2017).

3.4.2 Coding and Memoing

This researcher coded the interviews as quickly as possible. This helped to improve the interpretation of the data, thus enabling this researcher to avoid feeling overwhelmed by the amount of information (Bryman, 2016). As proposed by Wilson (2017), for this study, this researcher decided to use thematic coding to find more abstract thematic patterns in the coded data. Wilson (2017) cites Corbin and Strauss’s (2008) use of the term axial coding to describe this method.

Many codes were created early on in the analysis. Later, it transpired that some codes proved to be valuable, while others were not (Bryman, 2016). Open coding of this investigations’ data evolved into axial coding by focusing on the most prominent phenomena in the data through the discovery of underlying causal links (Charmaz, 2006)

(see Appendices 20 and 21). To swiftly write down her ideas, questions, and interpretations of a specific instance of coding, this researcher used NVivo¹⁰ for coding (Wilson, 2017).

A comparison was made between the codes and the transcriptions to determine whether the same phenomenon was described by more than one word or phrase (Bryman, 2016). This researcher prepared memos about the categories after coding a few occurrences, as recommended by Glaser and Strauss (2006). Memos served as a means of documentation and as a springboard for reflection (Bryman, 2016). During this research, memos were useful, not just as a means of self-reflection but also as a way of keeping track of one's thoughts at various stages of data comparison. This researcher kept track of her coding progress in the form of memos that were an easy method to keep track of the steps she took during the analysis process. Memos were written in the preferred and most convenient format for this researcher (Charmaz, 2006).

Explanatory codes were elevated to higher-level codes and further developed (Charmaz, 2014). As suggested by Ryan and Bernard (2003), this researcher looked for topics that emerged repetitively in the data to discover themes. She further looked for metaphors that the participants used to express their thoughts and for topics presented in a variety of ways by the interviewees. She additionally looked for language connections, reflecting on what was not in the data, and utilising social scientific concepts. As proposed by Bryman (2016), this researcher attempted to draw links between various ideas and concepts, while analysing the implications of these links in light of the existing literature. Consequently, she began to formulate some broad theoretical hypotheses regarding her findings.

¹⁰ NVivo is a programme designed specifically for analysing qualitative data on a computer.

3.4.3 Constant Comparison

According to Creswell (2012, p. 434):

Constant comparison is an inductive (from specific to broad) data analysis procedure in grounded theory research of generating and connecting categories by comparing incidents in the data to other incidents, incidents to categories, and categories to other categories. The overall intent is to “ground” the categories in the data.

For this research, each data set was constantly compared with other data sets at every stage of coding (Glaser & Strauss, 2006). Insights were evaluated against data to determine whether they held up. Data sets were re-examined to see whether the revised interpretations explained the participant's other remarks (Wilson, 2017). This researcher further verified with the participants whether she had understood their point of view by checking her own interpretation with them as Charmaz (2006) suggests. A comparison of multiple conceptual levels of data analysis is what motivated theoretical sampling and the continuous collection and creation of data (Birks & Mills, 2015). This researcher was however well aware that a theory could not be developed within the time restrictions inherent in the course.

3.4.4 Developing a Storyline

Birks and Mills (2015) name two functions of storyline in grounded theory: it helps develop the ultimate theory and then communicates it to the reader. Therefore, this researcher sought to transform concepts into a storyline consumable for readers, while also reflecting the analysis.

According to Birks and Mills (2015), theoretical sensitivity is used at its highest level to give an abstract explanation of the study findings when writing a storyline. As suggested by the authors, this storyline approach worked well for this researcher because it facilitated integration, allowing this researcher to communicate her theory in a way that caught the core of the participants' experiences. As further recommended by Birks and Mills (2015), this researcher added to, supported and validated pre-existing theories, while explaining and reinforcing the worth of her own contribution thereby helping to integrate the work of others into her storyline.

As proposed by Birks and Mills (2015), the use of a storyline helped to come up with and refine this study's conclusions. During the research, the storyline approach made it easier to spot gaps in the theory as it developed, while enabling this researcher to explain the connections between the various concepts that go into it. The storyline further served as an explanation for the hypothesis, thus explaining the phenomenon being studied (Birks & Mills, 2015).

3.5 Strengths and Potential Limitations

By demonstrating the effectiveness of the Bee-Bot for the evaluation for learning mathematical concepts, this study has added to the current body of available literature. That is indeed one strength of this study. Other strengths include the intrinsic conclusiveness of the grounded theory technique that allowed this study to serve as a systematic attempt to investigate the association between the Bee-Bot and the teaching and learning of mathematics, based on a recognised method of data collection and analysis.

As recommended by Glaser and Strauss (2006), the systematic use of diverse approaches, measures, and strategies within the framework of grounded theory allowed for

a more logical approach to getting to the bottom of the matter. Prior to collecting data and analysing it, this researcher also used knowledge and existing literature to develop theoretical sensitivity that, in the long run, led to this study taking unexpected turns, requiring this researcher to interact with the participants and the data in great detail. The theory is still tentative at this level, but comparable findings in prior research suggest that the present findings seem to have applicability, at least, within similar contexts and people for the same subject matter.

Undoubtedly, this research encountered some potential limitations. For instance, the availability to data and this researcher's personal qualities controlled what could be uncovered (Corbin & Strauss, 2008). Meanwhile, due to time constraints, the sample size was limited. Furthermore, in the axial coding stage, the sample of experts used to collect data was quite small and may provide the appearance of unsaturated data. Saturation was hampered since the researcher was constrained in how much she could do due to the few interviews necessary for the course, limited further by the time structure of the course itself. Despite this, certain categories appear to be well-developed, while others appear to show promise of being highly developed.

It is possible that the participants, especially children, may have understood the questions in ways that this researcher did not intend. Due to time restrictions, theoretical sampling was restricted to what was being studied, rather than who was pursued for emerging ideas. Finally, this study's findings cannot be applied to the entire population.

3.6 Ethical Considerations

The Faculty of Education Research Ethics Committee and the University Research Ethics Committee both granted ethical approval for this investigation. Prior to recruitment,

Permission letters were sent to the Director at the Directorate for Learning and Assessment Programmes of the Ministry for Education, the Head of College Network, and the Head of School. Furthermore, the study was discussed with the participants in person and via the information letters sent to an Education Officer, Head of School, teachers, pupils, and their guardians/parents (see Appendices 8, 9, 12, 13, 14 and 15).

In preparation for the research, this researcher did her utmost to recognise and prevent ethical pitfalls, such as, the need for informed consent or maintaining the confidentiality of participant information (Engward, 2013). Indeed, as suggested by Roth-Cline and Nelson (2013), for this research to take place, the educators received consent forms, while the pupils received assent forms. Meanwhile, the pupils' parents/guardians provided informed consent. A discussion of possible risks, advantages, and alternatives to research engagement was also required for voluntary and informed parental permission. A similar process was undertaken to gain the participants' consent.

Due to the need for parental approval, this researcher sought to avoid loading the children's assent form with the same knowledge and choice criteria as the adults' informed consent form (Roth-Cline & Nelson, 2013). According to Creswell and Creswell (2018), "you need to have participants sign informed consent forms agreeing to the provisions of your study before they provide data. This form contains a standard set of elements that acknowledges protection of human rights" (p. 147). There was clear communication of this study's aims to the participants, both verbally and in writing. Meanwhile, ethical issues, such as focus group or interview confidentiality, were disclosed. Additionally, the analyses and classifications could be re-examined after member checks to ensure their accuracy (Creswell & Creswell, 2018).

Merriam & Tisdell (2016) note that in certain cases of interviewing, respondents may feel that their privacy has been violated, they may feel uncomfortable by particular questions, and they may share things they never intended to reveal. Therefore, as proposed by Creswell and Creswell (2018), to protect the privacy of the participants, only pseudonyms were utilised instead of their actual names. Each participant was also given a briefing on their rights as part of the procedure before the interview began. Whenever a pupil was interviewed more than once, they were asked if they wished to continue participating in the study. Furthermore, the participants had the opportunity to withdraw from the study at any moment during their participation.

As recommended by Creswell and Creswell (2018), this researcher kept all the collected information in a safe place. Anonymised data and recordings were only accessible to this researcher, who was also the only one who transcribed and analysed the data obtained from the focus groups and interviews. The interviews and focus group interviews were conducted in Maltese and later transcribed and translated into English. Meanwhile, due to data protection concerns, any personal identifiable information has been withheld in this write-up. To avoid identifying the location, this research is based simply on a Maltese State school that was chosen mainly for practical and logistical reasons since the researcher is also a teacher at the school.

After careful consideration of the issues of deception and protection of subjects, other concerns had to be dealt with in the field as they emerged (Merriam & Tisdell, 2016). For this researcher, the contextual philosophical perspective comprised her practical ethical abilities of avoiding prejudice, reporting accurately, and utilising information properly.

According to Patton (2015), to prove the credibility of qualitative research, it is necessary to look at the credibility of the researcher and the methodologies used.

3.7 Conclusion

Using Grounded Theory techniques, this study produced high-quality data and an accurate picture of the students' and educator's experience with the Bee-Bot. This research did not segregate sampling, data gathering, and data analysis as independent stages. Instead, they were viewed as a continuous cycle of data gathering, analysis, and sampling (Elliott & Lazenbatt, 2005). Meanwhile, the research findings and ideas were not discovered but rather constructed by this researcher through her interactions with the participants and her emergent analyses (Charmaz, 2006).

The concept of this study was based on this researcher's perspective. Charmaz (2006) states that "different researchers may come up with similar ideas, although how they render them theoretically may differ" (p. 130). This constructivist approach aimed to reveal the viewpoints and behaviours of individuals (Charmaz, 2006), since children, adult participants, and researchers alike learn about the world through their own personal experiences, thus influencing and modifying the world around them (Ackermann, 2001).

Chapter 4

RESEARCH FINDINGS

4.1 Introduction

This chapter presents the findings of this research. The main research question and its two subsidiary questions were each addressed by an inductive analysis of the data following Grounded Theory methods. As explained in the previous chapter, this research experience began by locating suitable participants that is students on one side and educators on the other side to gather grounded data. The one-to-one interviews with educators were significant in gaining a better understanding of the professional perceptions of the efficiency of the Bee-Bot in the assessment for learning mathematical concepts. The professional perceptions of educators are attributed to their expertise in utilising the Bee-Bot for mathematics assessment in the context of learning. Table 4.1 provides pertinent information about the adult participants. Meanwhile, the focus group interviews with minor participants were vital in gaining insight into the children's perceptions.

Name of Participant (Pseudonym)	Gender	Age	Level of Education	Profession
Oscar	Male	44 years old	Doctoral degree	Education Officer
Pippa	Female	47 years old	Postgraduate Diploma	Head of School in a State school
Jane	Female	40 years old	Bachelor's degree	Year 1 teacher in a State school
Maria	Female	64 years old	Matriculation Certificate	Year 1 teacher in a State school
Janice	Female	24 years old	Bachelor's degree	Year 1 teacher in a State school

Table 4.1: Adult participants' information

The results from the gathered data are presented in two sections, one for the adult participants and the other for the minors. The data were then continuously compared with the aim of improving the understanding of the results. The adult participants unanimously agreed that the Bee-Bot motivates young students and is excellent for fostering critical thinking skills. The Bee-Bot is also adaptable to a variety of mathematical concepts, such as measuring length, addition, and counting, and for measuring students' mathematical understanding. Figure 4.1 demonstrates the major findings of this investigation.

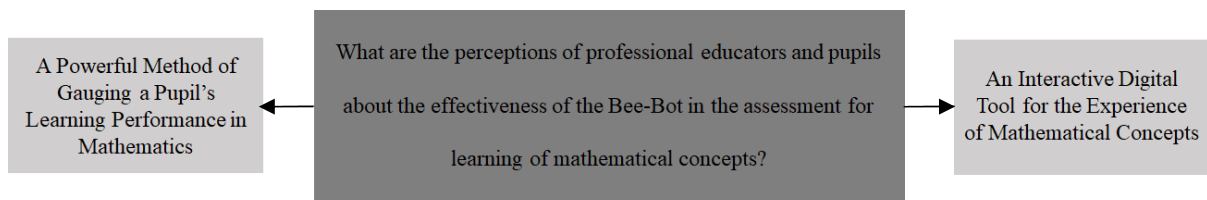


Figure 4.1: A representation of the participants' views on the Bee-Bot to answer the main research question.

4.2 A Powerful Method of Gauging a Pupil's Learning Performance in Mathematics

The adult participants' perspectives are included under the key finding 'A Powerful Method of Gauging a Pupil's Learning Performance in Mathematics'. The qualitative data was coded and organised such that significant themes and their relationships could be observed. The educators' encounters with the Bee-Bot informed the development of the codes for the identification of the themes, representing their varied viewpoints and personal experiences, as depicted in Figure 4.2.

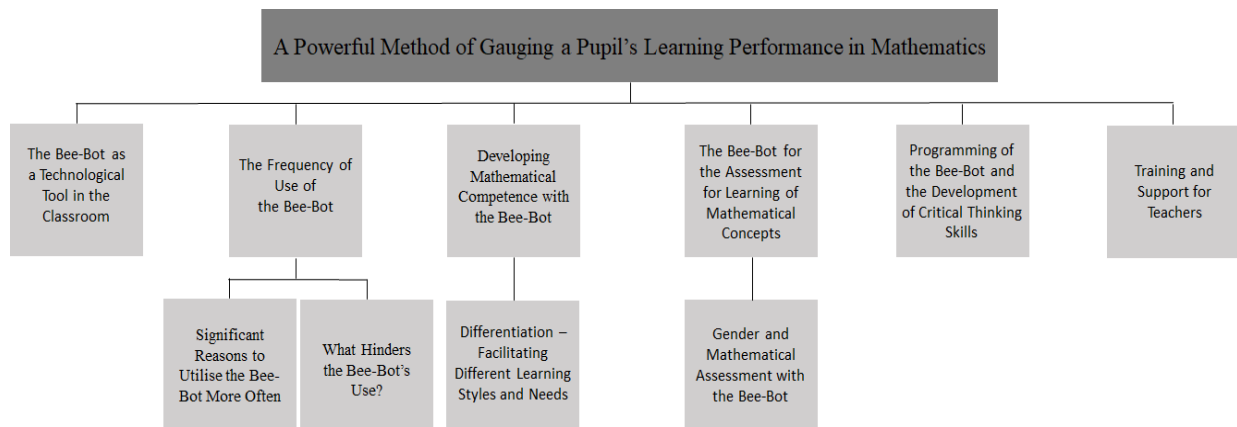


Figure 4.2: The Key Findings of the Adult Participants' Views

4.2.1 The Bee-Bot as a Technological Tool in the Classroom

One of the educators, Oscar, views the Bee-Bot as a tool that facilitates the development of 21st-century skills. This educator with post-graduated training asserted that the Bee-Bot motivates pupils to plan ahead. He explained that the student progresses from simple programming to advanced programming later on and that the student exercises mathematical abilities, such as counting and calculating where the Bee-Bot should go. According to Oscar and Maria, the use of the technological device Bee-Bot fosters attentive thought and critical thinking. It also aids in the development of computational abilities in pupils.

Oscar: ... so it leads children to think in advance ...the most important thing is how s/he is thinking, she is calculating, when s/he needs to reach and these are very important skills which we call the 21st-century skills ...

Maria: They are thinking critically because they are going to use something that is technological ...

Meanwhile, for Pippa, Jane, and Maria, when technological tools are incorporated into the teaching and learning process, students are motivated and inspired to perform. Jane expressed her desire to continue having access to and using these teaching and learning tools. Maria compared the Bee-Bot to tablets and other similar devices that pupils use in their leisure time, adding that the Bee-Bot motivates pupils to improve their attention span by stimulating their interest, keeping them alert, engaged and making them feel challenged to perform accurately.

Pippa: ... if used properly, it could be a very motivational tool for students.

Jane: ... may we keep finding them useful at school, these teaching and learning tools ...

Maria: ... when they are challenged with the Bee-Bot, they are more, quicker to, you know, get the correct instructions since it stimulates their curiosity as well.

One educator, Pippa, claimed that the use of technological tools during teaching and learning might be detrimental to a pupil who is not particularly interested in technology. However, this educator observed that, when the Bee-Bot is utilised sparingly during lessons, pupils look forward to utilising it, hence motivating them. On the other hand, Janice remarked that the Bee-Bot is accessible to all kinds of learners, whether they are auditory, visual, or kinaesthetic learners.

Pippa: If students are not so technological, they can be a little bit disadvantaged, but on the whole, I think that, since it is a new method not frequently used by teachers, students are motivated and look forward to using it.

Janice: I believe that the Bee-Bot caters for every type of learner because, obviously, if a child prefers auditory learning, they can listen to instructions and hence, they can move on. If s/he is visual, they can observe. Kinaesthetic types obtain experience.

4.2.2 The Frequency of Use of the Bee-Bot

Educators find the Bee-Bot readily accessible to teachers because this device may be found in many Primary schools. Oscar and Pippa stated that the Bee-Bot should not be utilised too often, so that students do not become too accustomed to it.

Oscar: ... we have a number of Bee-Bots also in schools ... it is important that one, like any other tool, does not utilise it superficially ...

Pippa: If it is used frequently, students will get used to it and will no longer feel enthusiastic and motivated.

4.2.2.1 Significant Reasons to Utilise the Bee-Bot More Often

One educator, Janice, utilised the Bee-Bot five times during the current academic year and once more when practising a game created by the school called 'Ups and Downs', which is played with the Bee-Bot. For her part, Jane reported using the Bee-Bot often and for a variety of subjects, while Maria uses it once or twice every term.

Janice: I have utilised it five times, apart from the 'Ups and Downs' game ...

Jane: ... I use it frequently and for different subjects.

Maria: ... maybe once or twice every term. So, a maximum of six, six times.

Pippa mentioned the "Tikka Matematika" initiative, which attempts to promote solid pedagogical methods in mathematics education. According to her, the teachers utilised

the Bee-Bot more frequently throughout one scholastic year due to the school's participation in this initiative. She also discussed the development of the 'Ups and Downs' game that promoted the usage of the Bee-Bot. According to this educator, this year, the teachers may be utilising the Bee-Bot less, owing to the IT support teacher introducing them to software that uses the Bee-Bot online.

Pippa: Last year, Year 1 and Year 2 teachers used it regularly since the school took part in 'Tikka Matematika'. A game, 'Ups and Downs', was designed ... so that students played it, and they had to use the Bee-Bot. This scholastic year, only a few Year 1 and Year 2 teachers used it, while some KGEs use it with regards to a topic they are discussing with their children.

4.2.2.2 What Hinders the Bee-Bot's Use?

According to Maria and Janice, the Bee-Bot can be utilised more often. Janice thinks that the frequency of use would depend on the principles being taught. She believes the Bee-Bot might be used to practise counting and direction skills, but she could not envision how it could be used to teach weight.

Maria: ... if you have the time to utilise it, obviously and because children enjoy using it.

Janice: I believe it can be used frequently, but then, it depends on the type of concepts. Alright, for example, counting, directions, those are alright, but, for example, if we are doing weight, I do not imagine using the Bee-Bot to teach weight.

Maria pointed out that there is not enough time to make the necessary resources for conducting assessment using the Bee-Bot because of the broad curriculum that is delivered.

According to her, a significant amount of preparation is required before she can make effective use of it. On the other hand, she is well aware of the fact that pupils like utilising the Bee-Bot.

Maria: ... you have a vast syllabus, eh, in order to utilise the Bee-Bot, you need to prepare a lot of work, you need to use, you need to prepare flashcards, you need to prepare pictures, eh and also, you need to make some assessment ...

4.2.3 Developing Mathematical Competence with the Bee-Bot

Maria noted that, via the use of the Bee-Bot, pupils are more eager to respond properly and inquisitively when compared to the traditional learning method. For his part, Oscar explained how unmotivated pupils would not achieve learning at its full potential, emphasising that the educator should teach a concept through other means, apart from the Bee-Bot, so that the pupils would not get too used to the Bee-Bot and lose interest.

Maria: When it is a normal question, you would not know whether they have understood what you are explaining immediately, but when they are challenged with the Bee-Bot, they are quicker to, you know, get the correct instructions ...

Oscar: ... if the device motivates, there are perhaps other things that are more important, whether it is meeting the aim or not, whether it is meeting the aim of computational thinking ... motivation is a factor, we cannot ignore it, as we know, children who are not motivated would not learn much ... but then, they might get used to it and one should not rely on it alone ...

Janice and Jane mentioned that the Bee-Bot helps keep pupils involved, which may be due to their use of a movable electronic device that assists them in achieving their objective, while making teaching and learning more engaging.

Janice: ... I believe it keeps them engaged. Even the fact that they are using something electronic, not just using a pencil or playdough, but they are observing something that is moving ...

Jane: ... it motivates children, it makes teaching and learning interesting for them ...

Janice asserted that the Bee-Bot can offer pupils the opportunity to develop the skills that they find useful in their everyday lives and open the door to their independence. She believes that, by utilising the Bee-Bot, pupils would not only acquire the skills, but would also understand the purpose behind each skill. Through group work, according to Janice and Jane, pupils could build their capacity to interact and communicate with others, while constructing their own learning through current experiences that build on prior learning.

Janice: They are obtaining certain concepts that they will apply in their future. In reality, I think it provides them with the skill of independence, in a way, because children would know the purpose, not just doing something for the sake of doing it, but there is a purpose behind it. And even, for example, they start reasoning ...

Jane: ... they are working as a group, turn-taking, sharing of ideas, you tackle many aspects, and there is communication, they communicate with each other, they discuss ...

Jane and Janice agreed that, with the help of the Bee-Bot, students are exposed to a wider range of mathematical concepts than the educator would have planned. Janice claimed that, even when not explicitly planned, pupils may learn a variety of mathematical concepts by interacting with the Bee-Bot. According to this educator, using the Bee-Bot enables educators to seamlessly transition into the next mathematical concept to be taught in the class.

Jane: ... for example, if they are programming, right, they need, to move it according to the need. They are doing, counting, value, I mean, you would address that aspect as well.

Janice: ... the Bee-Bot does not only draw out just one concept. While you are practising, using the Bee-Bot would address more concepts that were perhaps not intended to be tackled on that day ...

According to some of the educators, the teacher can utilise the Bee-Bot for the scaffolding of mathematics teaching and learning, as well as for consolidating learning and determining whether students have attained the lesson's learning objective.

Janice: ... also scaffolding since you are always, like, repeating. I mean, while you repeat, you can use the Bee-Bot to, for example, if they did, they tackled a concept such as left and right ... you can use it also as a conclusion to make sure that the concept has been grasped.

Jane: ... if we begin with numbers, number recognition, right, number value, you can begin activities about them and then, when you progress to addition, subtraction, then you can advance ...

Janice and Jane described the Bee-Bot as a helpful tool, praising its ability to improve teaching across a wide range of topics and subjects. Jane also emphasised that the Bee-Bot's flexibility makes it a great tool for teachers to experiment with new approaches to teaching once they and their pupils become accustomed to using it.

Janice: I find it very helpful for children, even for counting and directions ...

Jane: I find the tool very useful for teaching and learning, first of all, it enhances what I am teaching to the students, while utilising it at the same time for assessment ... you can integrate the Bee-Bot with any subject and any topic, there is no limit to what activities you can create with it, ... (pause) then with its help, you would be able to make the necessary assessment.

The capacity to experiment as a means of understanding and learning was emphasised as crucial by Pippa, Maria and Oscar, who believe that experiential learning boosts students' interest and passion for a subject, adding that, by utilising the Bee-Bot, pupils may investigate their own learning.

Pippa: ... I think children love to explore and investigate; so, it will help in their teaching.

Maria: ... practising hands-on and children of a young age love it a lot, when they practise, you do not need to impose on them ... This is similar to doing a Science project. Do you understand? They are engaged hands-on, they are observing, investigating ...

Oscar: ... instructions should be there, but children, we need to understand, need to experiment ...

Indeed, Oscar argued that, if pupils do not have the opportunity to experiment with their learning in the Early Years, they may find self-directed learning at home more engaging than classroom teaching. This educator further highlighted the importance of experimentation by pupils, seeing the Bee-Bot as an excellent learning tool. According to this educator, it is fine for pupils to put incorrect codes into the Bee-Bot and children may follow the Bee-Bot's instructions, but they should also be encouraged to explore. Maria concurred, stating that, owing to the tactile nature of the Bee-Bot, students may work with it without having to revert to pencil and paper.

Oscar: ... but teachers need also to understand that children need to be left to experiment ... like teaching and learning at home is interesting, formal teaching and learning is boring for children ... The child can utilise the Bee-Bot and move it into a box that has nothing to do with what he had to do.

Maria: ... it is something tangible with which they can work with ...

Jane and Maria commented on how using the Bee-Bot allows students to collaborate. According to Jane, as they wait for their turn to programme the Bee-Bot and debate other coding and programming alternatives, pupils get the chance to practise turn-taking. Meanwhile, for Maria, when there are so many pupils in a class, group work can be effective, and while working with the Bee-Bot, a teacher may choose to group pupils with varying levels of ability so that they may learn from and support one another, or s/he may choose to organise pupils by ability and then modify the task for each group.

Jane: ... it involves group work ... turn-taking, discussion among children, and also with the teacher.

Maria: ... since you have so many in the classroom, you may prefer to distribute them into groups. It is like doing group work, and it is important to, for example, distribute them according to their abilities.

Janice and Maria stressed the importance of listening to and following instructions. According to these educators, it is essential for pupils to be able to listen attentively, comprehend and adhere to provided instructions. Maria thinks that, using the Bee-Bot would encourage pupils to work harder to get the appropriate answer while working in groups. Janice explained that, by using the instructions, pupils would be able to progress from one step to the next, while learning a mathematical skill using the Bee-Bot.

Maria: ... they need to pay more attention, listen to the instructions, for the instructions. I think also, due to the presence of other children, eh, so they, to avoid embarrassment, they pay more attention than when they are in class since they would be showing their capabilities, eh, so the answer, they get it correctly.

Janice: ... when children are trying something new, they are actually doing something from scratch, which, with instructions, they build up one by one.

Oscar feels that attitude is the issue that must be addressed, emphasising that digital technologies should be utilised to attain the required abilities. This educator argued that there is no technique for calculating the development of digital abilities throughout the early school years of pupils since the usage of digital tools is at the discretion of the teacher. According to this educator, pupils have the right to learn and improve their digital abilities.

Oscar: I think more needs to be done for the mentality in general, the principles in general as to how particular skills are achieved, there are digital resources included

and then, one arrives at the teacher. I think that, from the Early Years until the Sixth year in the Primary, there is more to be done to ensure that certain teaching and learning has been achieved ... whether you utilise the Bee-Bot, whether you use digital, digital tools, it is the teacher's decision. Erm and this is not bad, that it is the teacher's decision ... the student is entitled to possess particular digital skills ...

4.2.3.1 Differentiation – Facilitating Different Learning Styles and Needs

Oscar remarked that children in the Early Years must learn via the use of tangible objects and their senses. He noted that the Bee-Bot supports a variety of learning styles since it allows pupils to develop their senses due to its ergonomic design and light, sound and motion that excite pupils' senses. He also observed that the Bee-Bot mat may be customised with various colours or images to make it visually appealing and suitable for visual learners.

Oscar: ... first of all, during the Early Years, the sense of tangibility is very important, tangibility: to feel, to hear, eh and this device is adapted for those purposes. The fact that, even its shape, it can wrap around the hand, which means that the way it is made can take the shape of the hand, of the boy or girl, so, in itself, even the buttons, also the sounds, also the fact that it moves ... the mats in themselves can be colourful, with pictures, so maybe, one goes to the shop, the Bee-Bot and then, it went somewhere else, there is a lot, this is also visual in itself, it is also a way for the child to watch and hear.

According to Oscar and Janice, the Bee-Bot provides learners with tangible experiences since they can witness the robot moving and arriving at its objective. These educators believe that a pupil's ability to learn is greatly aided by such visual aids.

Oscar: ... the fact that students are observing and they manage, they manage to get there in a way that they can see that they are getting there, not simply just speaking ...

Janice: It would help most those who are visual since they are observing the process happening ... once they observed the process happening, I think it helps a lot more to memorise it.

Alternatively, according to Oscar, the pupil may decide to utilise the Bee-Bot without sound, making it more accessible for a variety of learning requirements. Jane remarked that all pupils are eager to utilise the Bee-Bot, regardless of their learning needs.

Oscar: ... one considers the particular need, I am speaking in terms of, perhaps having movement, maybe you have sound, they can also be removed ...

Jane: ... when I had particular cases, I mean, always, we tried to involve them to make use of it. I do not think that, children would still involve themselves.

Some educators indicated that the Bee-Bot accommodates many learning styles, although they feel that visual learners may have an advantage when the Bee-Bot is used to teach mathematics. Janice pointed out that pupils who are visual learners have an advantage since they can understand a mathematical concept or expand their understanding through a Bee-Bot activity, even if they do not fully understand the teacher's explanation. For her part, Maria explained that visual learners might quickly arrive at the

solution by using the Bee-Bot with the aid of observation and the incorporation of images.

Pippa said that all of their students benefited from using the Bee-Bot since it uses a multisensory approach.

Janice: ... there are those who are visual, those who are kinaesthetic and those who are auditory. It would help most those who are visual since they are observing the process happening ... I believe it would be advantageous because, for example, if they do not understand the explanation, they are observing the process as it is happening ...

Jane: ... apart from giving instructions to the Bee-Bot, you can also observe the visuals included as well, like pictures and maybe words and the like ...

Maria: More visual, they can work out a sum right away. So, they get to the answer instantly.

Pippa: ... a multisensory approach helps a lot. Not only for visual learners, but all students.

Janice noted that the Bee-Bot aids her teaching and learning since it allows her to present as many examples as she desires to pupils who are having difficulty grasping a mathematical concept. She also divulged that, when pupils are working on a mathematical concept with the Bee-Bot, she can observe and determine whether the pupil has comprehended the concept or requires more instruction.

Janice: What is good about the Bee-Bot is that there is no limit to how much you can give and for example, if you observe that there is the need for three examples for a

child to understand, while you are assessing, you can say, 'Look, this worked, this did not work'.

Some of the interviewed educators claimed that the Bee-Bot is a beneficial tool since it accommodates several learning styles, namely, experiential, tactile, and visual, therefore meeting the needs of a variety of pupils.

Janice: ... I think it caters for every type of learner, in reality, that makes it a good tool ...

Jane: ... one style is hands-on because children are engaged with hands-on ... there is thinking ...

Some educators indicated that the Bee-Bot is also suitable for non-verbal pupils, adding that pupils use technological devices to communicate, thus being successful in different learning tasks. Bee-Bot tasks, according to Maria and Oscar, facilitate an educator's comprehension of pupils' strengths and areas for improvement, allowing for more effective assessment. Janice believes that pupils feel more at ease when accessing learning through the Bee-Bot, adding that they also feel more involved since they can practise a task with their peers without the need for extensive verbal communication.

Jane: Yes, those who are non-verbal can also utilise it.

Maria: In fact, in class, I have a boy who is non-verbal and we use many technological devices, for example, we have the interactive whiteboard, ... we use the computer a lot because he cannot communicate the answer, ... so he shows you, kind of, the way forward, as he does it. You discover the child's needs later on because you get to

know the boy or the girl even more. So, these things help children manage to reach solutions better.

Oscar: So, as the learning process is now easier for them, but yes, it is also a way to demonstrate their work, right, because there is no difference when you are watching, presenting something between a boy and a girl, irrespective of being verbal or non-verbal ...

Janice: ... they would feel more at ease and feel more included like their friends ...

Maria emphasised that the Bee-Bot stimulates the children's interest in learning and that the teacher would not have to exert much effort to gain the children's attention because children like hands-on activities and the opportunity to observe and discover.

Maria: ... when they are practising measure or weight or capacity. When they are practising hands-on, they are more interested ... there is the involvement of investigation, and that is what children like a lot.

One potential drawback that was mentioned by Maria was that the pupils could have problems waiting their turn.

Maria: ... the problem is that, for example, those children who are, who are slightly fidgety may want to take a turn every time.

According to Pippa, the implementation of differentiation in teaching and learning depends on the teacher.

Pippa: ... I think it depends also on the effort of the teacher to include differentiation.

4.2.4 The Bee-Bot for the Assessment for Learning of Mathematical Concepts

Oscar finds the Bee-Bot a useful tool for assessing the acquisition of mathematical concepts since it may assist a pupil in obtaining a learning outcome. Maria noted that the Bee-Bot fosters self-confidence since it aids the pupil in completing the assigned activity successfully.

Oscar: ... I think it is mostly effective because it helps the child to manage a particular task. When the boy or girl is given a particular task, the aim is thus met.

Maria: So, with the Bee-Bot, which helps a lot, they can demonstrate their abilities and that they are progressing. Also, they feel more, that they are succeeding in the task you would have given them.

Some educators believe that the Bee-Bot is useful for determining whether a pupil has grasped a mathematical concept since the teacher may observe the pupil as s/he completes a hands-on task.

Janice: To extract certain concepts, as we are discussing, above and below, up and down, left and right, also forward and backwards. I find it very useful since it is hands-on ... you can use it also as a conclusion to make sure that the concept has been grasped.

Jane: ... you can choose any topic you like when you use the Bee-Bot, while at the same time, you are making the assessment, for example, we are doing counting, right, also, since they need to programme it, they are doing counting, if we are doing the topic on direction, they programme the direction it needs to go. So, at the same time, you can make an assessment.

Maria: If you are teaching a mathematical concept, you would find out whether the boy or girl got it or not ...

Pippa: ... students are actually doing the activity; so, teachers can observe and gain feedback to realise if students understood the learning intention ...

According to Maria, the Bee-Bot is successful since it delivers immediate assessment results for mathematics.

Maria: Effective because, eh, you get the results there and then.

Oscar, Janice, and Jane claimed that the Bee-Bot may be used to evaluate a variety of mathematical topics, including direction, weight, position, capacity, and counting.

Oscar: ... you have that concept as well, East, West, North, South ...

Janice: ... I think it is very useful for directions, positions and the like.

Jane: They are doing counting, value ...

Jane: ... if you are teaching keywords on capacity, they reach a word with the Bee-Bot, they read it, they say what it means.

Janice and Pippa discussed how mathematics assessment may be approached, claiming that the Bee-Bot allows the teacher to monitor the pupil, determine his or her learning needs, provide correct feedback to the pupil and modify the teaching techniques to optimise the pupil's learning. According to Janice, throughout the early years of education, feedback is the most effective method for encouraging pupils to identify areas in which they need to develop.

Janice: Through observation, you observe them while they are using it ... Not, as we were discussing, simply using the Bee-Bot and that's it, but there is a purpose ... You give them feedback, ongoing feedback ... I think feedback is what helps children most as it is like you are reasoning with them ...

Pippa: ... allow teachers to improve and adjust their teaching ...

Janice suggested that, when a teacher encourages pupils to practise a task with the Bee-Bot, a pupil who would not have mastered the mathematical concept has the opportunity to indirectly achieve the learning objective. Meanwhile, Jane noted that the Bee-Bot is beneficial for assessing non-verbal pupils since the teacher may monitor their development and needs via hands-on practice using the device.

Janice: ... if you apply it for the whole class, he is still learning, he is still grasping the learning intention, but in an indirect manner ...

Jane: ... if they cannot communicate verbally, you can still assess particular topics ...

4.2.4.1 Gender and Mathematical Assessment with the Bee-Bot

Oscar, Janice, and Jane asserted that the Bee-Bot is viewed as a gender-neutral tool, where the performance of pupils utilising the tool is unaffected by their gender.

Oscar: ... it is gender neutral, that is, there is no difference ...

Janice: I don't think it makes a difference. All children have their own abilities. It does not, I don't think it affects, as in gender.

Jane: No, it interests all children. I do not see gender as imposing any differences.

Maria, however, emphasised that the teacher must be cautious when selecting images for Bee-Bot activities. She argued that learners may be disinterested or do not exert much effort owing to a lack of desire due to the chosen topic, hence perhaps impacting their mathematics learning assessment.

Maria: Maybe you need to consider the subject and what pictures you use that appeal to both boys and girls.

According to Pippa and Janice, it is not the gender of the pupils that determines how they are assessed in mathematics, but rather, their mathematical abilities and preferred learning method.

Pippa: It depends on the students' ability in math, even if they like the subject and if students like learning by using all senses and are interested and involved in the subject, I think it will help, but it doesn't make a difference.

Janice: It depends on the learning, the children's capabilities ...

Janice: ... when they start thinking, they give different options that I do not think would make a difference whether they are a boy or a girl ...

Maria noted that the environment in which pupils are engaged in the activity may influence the assessment. She believes that, if there are distractions and background noise, it may be difficult to evaluate the pupils' mathematical skills since they would not be sufficiently engaged.

Maria: ... the environment where they are would depend as well, whether it is in class, eh, if you are, for example, in the yard or outside. It depends because, if you are in the yard, there may be something that distracts their attention ...

4.2.5 Programming of the Bee-Bot and the Development of Critical Thinking Skills

According to Oscar, the Bee-Bot is comparable to the technological device Turtle in terms of programming. He claimed that, when students programme the Bee-Bot, they can develop skills in forethought and planning. Oscar also noted that, by using the Bee-Bot, pupils are helped to think critically and develop their cognitive skills. He further argued that, although certain skills “may be unwritten”, when using the Bee-Bot, pupils can enhance these skills, for example, peer-to-peer communication.

Pippa, Janice, and Jane agreed that the Bee-Bot enables pupils to discuss, interact, and solve problems within their teams. They added that, while communicating with their team members, the pupils would be answering questions to solve challenges, which would require them to exercise their critical thinking abilities while collaborating to find a solution. One of the educators argued that the Bee-Bot provides pupils with the opportunity to recognise that there are multiple ways to arrive at a solution in mathematics.

Pippa: ... but then, they must problem solve and figure out how to get the Bee-Bot, example, to the correct picture.

Janice: I think it also helps their critical thinking and problem solving. It helps them reason how to arrive to the solution ... I processed it this way, and he processed it in another way, that, I think, in reality, when children observe different examples, it helps them.

Jane: ... they need to think since, prior to programming it, you need to think.

Pippa remarked that, adapting questioning techniques to the task is an excellent strategy to utilise the Bee-Bot to promote and increase students' critical thinking. According

to Janice, the Bee-Bot draws out a wide variety of ideas that help meet the pupils' varying learning levels and demands.

Janice: ... it extracts a lot of different concepts and caters for different needs.

4.2.6 Training and Support for Teachers

According to Oscar, most teachers are familiar with the Bee-Bot and its utilisation. Meanwhile, Janice, Jane, and Maria learnt how to use the Bee-Bot through YouTube videos, teaching practice, support teachers, the Bee-Bot's instructions, experimentation, and trial and error.

Oscar: ... I know of few teachers, when I speak to them, who do not know what the Bee-Bot is. Therefore, almost all of them have heard of, more or less ...

Janice: I learnt from teaching practice, we had an IT teacher, who used to show us different gadgets and how they aid ...

Jane: ... I think the digital literacy teachers who actually demonstrated how to utilise it, but it can be easily used.

Maria: I experimented. You check the instructions and experiment ...

Oscar noted that the Directorate for Digital Literacy and Transversal Skills provides help for digital devices for classroom teachers through support teachers who are readily available in schools to give ongoing support. The support teacher was considered important by all the other interviewed educators.

Oscar: ... there are also a number of teachers within the Directorate for Digital Literacy who provide continuous support also to teachers ...

Jane: ... when we sometimes had the Maths support teacher, we used to come up with ideas how to utilise it ...

Pippa: I think ICT teachers can help. They deliver lessons, and teachers observe. They also can help them plan lessons by using a Bee-Bot as a tool. They can give them practical examples ...

Oscar added that teachers may learn more about how to use the Bee-Bot by watching videos on the Digital Literacy website and by following the video's instructions. He added that training on the Bee-Bot and its application is occasionally offered during CoPE¹¹ Sessions¹², particularly for Early Years educators.

Janice noted that parents of pupils in the Early Years should be provided with guidance on how to encourage their children to use the Bee-Bot online and on how to be more knowledgeable about the use of the Bee-Bot and other technological devices available at school.

Meanwhile, Oscar and Pippa argued that, when a teacher requests support to develop Bee-Bot-based activities, the support teacher provides assistance and sometimes also coordinates a lesson with the class teacher. Pippa highlighted that educators are provided with support for integrating the Bee-Bot with mathematical learning outcomes.

Oscar: ... there is a number of teachers who ask for support, and they manage to coordinate a lesson with the digital literacy support teacher.

Pippa: ... how to use the Bee-Bot by being linked to Maths learning outcomes and demonstration of activities, maybe also coteaching ...

¹¹ CoPE stands for Community of Professional Educators.

¹² CoPE Sessions consist of training delivered by or coordinated by the Senior Management Team or the Ministry for Education, Sport, Youth, Research and Innovation.

According to Oscar, the fact that teachers must adjust their teaching and learning to incorporate the Bee-Bot causes the most concern. According to this educator, the teacher may be concerned about the amount of time required to prepare the necessary materials to use the Bee-Bot. He claimed that, although a teacher may be concerned about the required resources, in reality, there would be minimal preparation necessary because a large amount of material is easily available.

Oscar: ... change is part of the difficulties that teachers would have.

Oscar: ... fear, obviously, is felt since you have the Bee-Bot, you need preparation; hence, there is the element of preparation, where one needs, it might be the case that, most of the time, preparation is not that much ...

Meanwhile, Janice receives assistance from the Learning Support Educators, who try their best to assist the pupils during the Bee-Bot activities, as well as from the school's Assistant Head, who promotes and appreciates the teacher's use of digital devices.

Janice: Also, even the LSEs, I think, they enjoy it as well because there is always their support ... the Assistant Head, they praise your effort in what you are doing, you are using something different with the children. You are ... you are utilising the tools that the school is buying ...

Nonetheless, Jane and Maria expressed a need for more training and assistance from the Maths Department, as well as more curriculum time for teachers to exchange and learn from one another's ideas.

Jane: Maybe they provide us with more ideas, other than how to use the Bee-Bot, but more concrete ideas, how one can integrate it with different mathematical

topics ... not really support, as such, but the sharing of ideas as well because I might have thought of a particular activity about a certain topic and another teacher has another idea that would be equally interesting.

Maria: If there is the chance that there is something, I don't know, maybe a CT¹³ from the EO¹⁴ of Maths support ...

4.3 An Interactive Digital Tool for the Experience of Mathematical Concepts

As illustrated in Figure 4.3, the following results demonstrate how the pupils regard the Bee-Bot as a mathematical learning resource under the key concept 'An Interactive Digital Tool for the Experience of Mathematical Concepts'. The pupils' diverse perspectives and personal experiences are reflected in the codes used to identify the themes in Figure 4.3, which were developed on the pupils' engagement with the Bee-Bot.

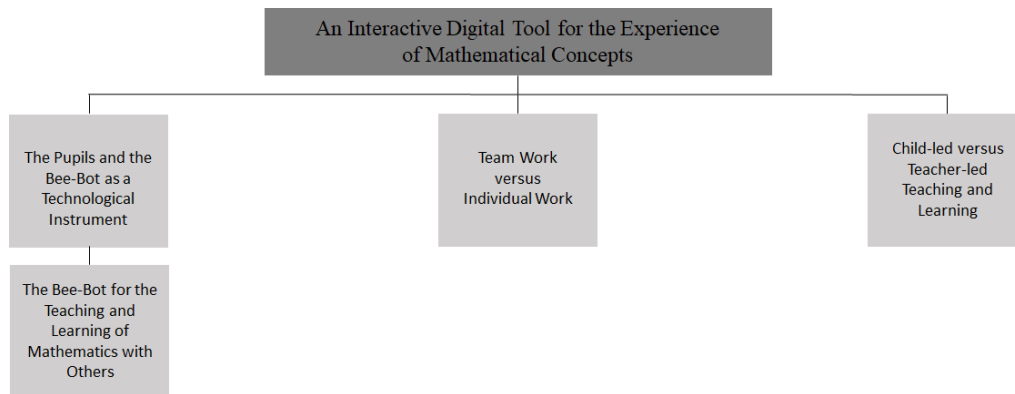


Figure 4.3: The Key Findings of the Minor Participants' Views

¹³ CT stands for Curriculum Time.

¹⁴ EO stands for Education Officer.

4.3.1 The Pupils and the Bee-Bot as a Technological Instrument

A young participant, Pam, compared the Bee-Bot to a wasp – which is similar in appearance to a bee for many children that this researcher worked with - and described its colours. Meanwhile, Paul, Bob, and John reported that they own a Bee-Bot and love playing with it.

Pam: Like a wasp ... It has yellow and black colours.

Bert: Me, if you press left or right, it moves left and right.

Paul: I have a Bee-Bot at home.

Bob: I have a Bee-Bot.

John: I have one at home as well.

The children showed familiarity with the Bee-Bot and said that they had previously used it. They compared it to a machine and a robot as well because it moves, has wheels, and is controlled by buttons (Tina, Lara and Bob).

4.3.1.1 The Bee-Bot for the Teaching and Learning of Mathematics with Others

Paul disclosed that his teacher taught him how to use the Bee-Bot, while Pam recalled that her Kindergarten 2 teacher had a Bee-Bot in class and that is where she first learned how to operate it. She also mentioned that she used to play games with the Bee-Bot and liked them very much. For her part, Stella stated that her favourite part is pushing the Bee-Bot's buttons.

Interviewer: How did you learn?

Paul: The teacher.

Pam: Right, Kinder 2 ... Because I had a teacher who had a Bee-Bot.

Interviewer: What did you do?

Pam: I play. We play games with the Bee-Bot.

Stella: Because we like it ... The buttons.

The young participants were requested to describe an activity they engaged in while using the Bee-Bot. Stella described using flashcards throughout the activity involving the device. For her part, Pam described the setup for the Bee-Bot activity in the classroom, while Ruth recalled that the pupils were required to take turns while practising the Bee-Bot activity.

Interviewer: Yes and what was this nice lesson you did?

Stella: With flashcards.

Pam: When I was in Kinder 2 with the children, I was staying at the back and we played with it. On the floor, but then, the teacher brought a table in the middle for us to play with it.

Ruth: ... but the teacher was not only involving me. We were doing the game one by one.

Lara: The Bee-Bot was counting to ten. Then, we were making letter circles and then, it would look for them on the paper.

Most of the participants preferred using the Bee-Bot to practise mathematical skills, rather than writing tasks or listening to teacher explanations. The majority agreed with this, notwithstanding their inability to justify their preference.

Interviewer: What would you prefer, using the Bee-Bot or using a paper and pencil?

Stella: With the Bee-Bot.

Paul: With the Bee-Bot.

Interviewer: Why would you prefer using the Bee-Bot instead of a paper?

Paul: It's nice.

Interviewer: Right. Why is it better playing with the Bee-Bot or listening to the teacher? What do you think?

Paul: Playing with the Bee-Bot.

Lara indicated that she can learn from both the teacher's explanation and the use of the Bee-Bot, while Bob and Ruth argued that the Bee-Bot is a toy and that toys could not be used in the classroom.

Interviewer: What do you think you learn more with, when the teacher explains or when you utilise the Bee-Bot? Or both?

Lara: Both of them.

Interviewer: You think that the lesson would be unpleasant with the Bee-Bot?

Bob nods.

Interviewer: Why do you think so?

Bob: Because it is a toy during the lesson and I do not like toys during the lesson.

Ruth: I do not like toys in the classroom, but I still like lessons about toys.

Most of the young participants, both boys and girls, like learning mathematical concepts such as numbers and calculations with the assistance of the Bee-Bot. This may be attributed to children having an insatiable curiosity for discovering new things. Bert believes that the Bee-Bot facilitates enhanced mathematical learning and is simple to use, possibly because it provides the option of multiple appropriate solutions.

Interviewer: Do you like practicing mathematics with the Bee-Bot?

Children (together): Yes.

John: So that we know what to do with it.

Lara: And we learn.

Interviewer: Do you enjoy doing numbers, sums with the Bee-Bot?

Children (together): Yes.

Interviewer: What can you learn with the Bee-Bot during Mathematics?

Bert: Follow the instructions and press the buttons and also the papers with numbers so that and you place them on the floor so that it moves on them and you say them.

Several participants, both boys and girls, argued that mathematical learning would be more enjoyable with the device since they would feel as though they were playing a game while learning. They argued that the teaching and learning of mathematics would alter constantly with the Bee-Bot. The students were asked whether they prefer to solve mathematical problems with the Bee-Bot or using pencil and paper. The majority of the participants indicated that they prefer to learn with the Bee-Bot.

Interviewer: What do you prefer? Learning mathematics and numbers with the Bee-Bot or by writing on a handout?

Kelly: With the Bee-Bot.

Dora: With the Bee-Bot. Because I like the Bee-Bot.

Bob: No, I do not like to write on a paper.

Interviewer: And why is it better with the Bee-Bot than on paper?

Tina: Because it is like you are playing at the same time.

Lara: It would be different, the Bee-Bot game would be different.

4.3.2 Team Work versus Individual Work

When asked whether they prefer to work on a Bee-Bot task alone or in a team, the majority of the young participants, regardless of their gender, indicated a preference for working in a group. For Ruth, working alone would make her unhappy, while Bob dislikes working alone. Meanwhile, John enjoys taking turns with the Bee-Bot when engaging in an activity.

Interviewer: How do you like to work with the Bee-Bot best, individually, in pairs or as part of a team?

Tina: Me, in a group.

Sara: Playing with the other children.

Dora: With someone else.

Interviewer: And why with other children?

Ruth: So that I do not feel sad ...

Bob: Because I do not like to play alone.

John: So that we have turns.

4.3.3 Child-led versus Teacher-led Teaching and Learning

The minor participants were asked whether they prefer to think creatively or follow the teacher's directions when completing mathematics problems using the Bee-Bot. The majority responded that they prefer the teacher's instructions and would seek the teacher's assistance in the event of difficulties.

Interviewer: When you have the Bee-Bot and you need to do something with it, a lesson, how do you know what you need to do?

Pam: The teacher tells us.

Sara: Someone has to tell you how to use it.

Tina: The teacher.

Sara: I prefer if there is someone who helps us so that, if I do not know how to use it, I would not break it for the teacher.

Interviewer: So ... when you encounter a problem while using the Bee-Bot in an activity, what do you do when you are doing the Maths lesson with the Bee-Bot and there is something which you do not know what to do, what do you do?

Stella: We ask the teacher.

Bert: Erm, the teacher telling me.

For their part, Bob and Lara prefer to experiment or follow the Bee-Bot's instructions to determine how to programme the Bee-Bot for the mathematical task. This might be because students could navigate their own way around the assigned work. Bob added that he prefers to arrive at a solution through critical thought.

Interviewer: Why would you prefer to think for yourself what to do with the Bee-Bot?

Bob: Because I like to think. I have a lot of plans on my mind.

Interviewer: Ok, what do you do if you encounter a difficulty and you do not know what you need to do during the Bee-Bot game?

Lara: I find the instructions, and I keep and I keep playing with the Bee-Bot ... I find the instructions, and then I start to try reading, and then I realise I need to press the buttons.

4.4 Conclusion

The participants in this research – children and educators - believe that the Bee-Bot can be modified effectively for mathematics teaching and learning. The minors concurred with the adult participants that the Bee-Bot, as a technological tool, encourages and engages pupils in learning, more than traditional teaching methods do. Both female and male school children said that they like using the Bee-Bot during mathematics tasks, confirming the educators' perception of the Bee-Bot technology as being gender-neutral.

The Bee-Bot has been cited as a useful tool for assessing students' progress in mathematics because it caters for a variety of learning styles, allows for immediate feedback on students' progress and boosts students' self-esteem as they use the tool for learning and group work. Additionally, it was mentioned that the Bee-Bot helps students develop

analytical and strategic thinking skills. However, the vast curriculum may make it difficult to find the time to prepare for the Bee-Bot usage in mathematical tasks. It was also said that schools may quickly obtain professional help from support teachers regarding the Bee-Bot and other technology. This research has further found that teachers would use the Bee-Bot more if they know about its mathematical benefits.

Chapter 5

ANALYSIS OF FINDINGS

5.1 Introduction

The aim of this study was to evaluate the perspectives of both educators and pupils in Year One when using the Bee-Bot in the classroom as a formative assessment tool for mathematics understanding. How does the Bee-Bot make learning and teaching better? What are the Bee-Bot's educational benefits and disadvantages? When conducting formative assessments in mathematics, does the Bee-Bot make the process smoother? How does the Bee-Bot cater for differentiation in teaching, that is, addressing the individual requirements of each and every pupil as they engage in teaching and learning? How effective is the Bee-Bot in the development of critical thinking skills and computational thinking skills? Does gender influence the efficacy of the Bee-Bot for the teaching and learning of mathematical concepts? The previous chapter presented the results of this investigation, this chapter will present the analysis of this rich data supported by the extensive literature reviewed in Chapter 2.

5.2 Data Analysis

This chapter analyses these findings by going into further detail on the correlations that may be drawn between this study and available research.

5.2.1 Gaining Competence in the Twenty-First Century

The findings indicate that this study's young participants feel that the Bee-Bot looks like a bee since its colours are mainly yellow and black. Similarly, Beraza et al. (2010) note that the Bee-Bot "is a big bee that pupils can program by pushing buttons on its back for

moving forward, backward, turning left, right, starting to move or deleting previous commands” (p. 551). Similarly, Di Lieto et al. (2017) explain that the Bee-Bot is a simple device that is shaped like a black and yellow bee.

Meanwhile, some of the younger participants in this research observed that, pushing buttons is necessary in order for the Bee-Bot to move. The students brought up this characteristic frequently, which was taken as an indication that they find it useful and motivating when they practise an activity that involves the Bee-Bot. Cutajar (2019) claims that, if given the right resources, very young pupils may teach a robot to move from one location to another. Using the Bee-Bot robot to train in computational thinking, Caballero-González et al. (2019) found that such “type of challenge allowed the students to strengthen their mental processes of critical thinking and spatial disposition” (p. 22).

In their research, Kalelioglu and Sentance (2020) found that students have the capacity to learn new programming approaches and enhance their programming abilities through the use of various kinds of physical devices. This looks to be consistent with the data that was gathered in this study, where an educator, Oscar, described the steps that a pupil takes, from learning the fundamentals of programming to reaching more complex levels of programming.

Some of the teacher participants maintained that, providing learners with access to technology, such as the Bee-Bot, helps their pupils improve their ability to concentrate and think critically, in addition to assisting them in acquiring the necessary computational skills. They perceive the Bee-Bot as a tool that pushes the pupils to apply, analyse, and evaluate the information that they learn. This is in line with the findings obtained by Cutajar (2019),

where robots can be a helpful and effective tool for the transfer of skills related to computational thinking. Cutajar (2019) further claims that “[c]omputer programming and ER¹⁵ have the potential to implement computational thinking skills in young students” (p. 30).

For Camilleri (2018), technology seems to pique a child's interest in learning and motivate him/her to recall what s/he learns. This research supports Camilleri's (2018) observation since some educators claimed that, utilising technological tools in the classroom increases the students' motivation and interest in the subject matter. Additionally, some authors claim that the Bee-Bot helps all learning types, thus accommodating all learners and allowing teachers to cater to their students' specific requirements (Spinarova & Vachalova, 2021; Schina et al., 2021; Lopez-Caudana et al., 2020). As a result of the research that was carried out for the purpose of this study, it was discovered that the Bee-Bot is beneficial to students who learn primarily through auditory, visual, and kinaesthetic means since it takes into account and supports the pupil's preferred mode of learning.

5.2.2 Utilising a Bee-Bot

According to Scicluna (2020), it is unreasonable to ignore the reality that Maltese State Primary schools have been outfitted with technology tools. However, the author observes that school administrators must ensure that digital resources are used to benefit students. This is consistent with this study's findings, that indicate that the Bee-Bot is easily accessible to teachers and can be found in a number of Primary schools across the island.

¹⁵ ER stands for Educational Robotics.

Niess et al. (2009) explain that, according to the Mathematics Teachers TPACK, educators may benefit from adopting technology to increase their productivity and competency, adding that it is within the purview of educators to investigate and assess new and current technologies designed to boost students' mathematical achievement. According to the findings of this research, the Bee-Bot is a useful tool that teachers are eager to implement across a wide range of curricular areas due to the fact that it is easy to integrate, simple to use, and can serve as a tool for assessing for learning mathematical knowledge.

The children who took part in the study showed that they were familiar with the Bee-Bot and they acknowledged having used the gadget before during prior years at school or during the present year. Bers (2010) argues that, through building and programming robots, educational robotics may promote active and interactive learning. The outcomes of the study demonstrate that the children participating in the study saw the Bee-Bot as both a machine and robot. A student (Bob) pointed out that robots are machines and since he has an interest in machines in general, he really enjoys using the Bee-Bot. Similarly, Mikropoulos and Bellou (2013) explain that educational robots are defined as 'physical machines', or tangible objects, that facilitate users' work with and the development of mental models.

Meanwhile, Highfield (2010) claims that the Bee-Bot and other robotic tools allow students to enjoyably and productively interact with complex mathematical concepts, adding that, when mathematical practices give multiple correct solutions, this "engenders flexible thinking and encourages reflective processes" (pp. 22-23). On the other hand, at least one of the educators (Janice) who participated in this research does not envisage herself addressing all areas of mathematics, particularly weight, while utilising the Bee-Bot. Her viewpoint is that the Bee-Bot is able to enhance mathematical teaching and learning,

but it cannot be customised to every mathematical topic that is being taught. Additionally, according to the findings of this study, due to the extensive curriculum, a teacher seldom has time to create resources and employ the Bee-Bot in the classroom. Indeed, Maria, one of the adult participants, believes that time is limited because she is required to teach a very broad curriculum.

According to Lee et al. (2013), if teaching and learning were unstructured, they would be more adaptable, and students would have more opportunities to explore, experiment, and discuss their findings with peers.

5.2.3 Constructivism

Hardman (2019) contends that technology can increase Primary school mathematics achievement if used alongside a pedagogy inspired by constructivism instead of traditional teaching. Technology-enhanced learning, which incorporates computers and other technology (Littlejohn & Pegler, 2007), improves traditional teaching methodologies by promoting “active participation from students” (Lam et al., 2021, p. 93). This is comparable to the findings of this study, where using the Bee-Bot makes pupils more eager to answer questions while becoming more curious about learning than traditional methods of teaching and learning. Therefore, the Bee-Bot assists pupils in becoming engaged in the learning process and contributing to it.

The results of this research point to the possibility that children could gain something from the type of experiential learning that is offered by the Bee-Bot, in addition to the opportunities to observe and inquire about the task at hand. This concurs with Lathifah et al.’s (2019) study that suggests that, using technologies that allow for direct investigation

and creation, constructivist learning forms the basis of educational robotics, giving students more possibilities to grasp abstract concepts.

According to this study's results, students gain knowledge by deriving significance from the events and activities that they participate in. This concept is essential to the field of educational robotics and it is a skill that can be honed through the application of the Bee-Bot in the context of the mathematics teaching and learning it provides. Hein (1991) observes that, since the learner engages in spontaneous and unplanned behaviour and learns by creating meaning to his or her experiences, assessment for learning is made possible by a constructivist approach, which forms the core of educational robotics, as we have already seen.

It transpired from this study that, instead of completing writing tasks or listening to the teacher's explanations, pupils prefer to use the Bee-Bot to practise mathematical skills. This demonstrates that the pupils favour gaining an understanding of mathematical concepts through the completion of hands-on activities, where they are given the chance to explore and investigate. Indeed, the vast majority of the young participants hold this viewpoint, despite the fact that they were unable to provide an adequate justification for their decision. Similarly, the National Research Council et al. (1989) assert that, through the use of technology, one "can enhance mathematical learning by extending each student's mathematical power" (p. 84). A study by Casler-Failing (2021) reveals that the use of robots helps students develop their mathematics analytical thinking skills and a deeper understanding of mathematical concepts.

It further transpired that the Bee-Bot is the preferred teaching method for basic mathematical principles among both male and female pupils. The majority of the

participants of both genders reported that, utilising the Bee-Bot to assist them in acquiring mathematical concepts such as numbers and calculations is a positive experience for them. According to the findings, the younger participants of both genders view the Bee-Bot activities as interesting, motivating, and helpful. It is possible that this is because children have an innate urge to learn new and different things.

The pupils prefer using the Bee-Bot as a tool to improve their mathematical abilities because of the freedom it gives them, that is, to interpret and make sense of what they are learning. It is indeed possible because the Bee-Bot gives the pupils the opportunity to conduct experiments, make discoveries, and learn new things. Similarly, Hardman (2019) claims that, using technology in conjunction with a constructivist pedagogy, rather than a traditional pedagogy, can improve the mathematical ability of Primary school students.

5.2.4 Foster a Love of Learning: Child-led Learning

This study found that the use of digital tools in the classroom boosts students' passion for learning mathematics. The use of digital gadgets instils an eagerness to learn thereby facilitating the acquisition of mathematical skills. Similarly, Cobb (1998) asserts how students' motivation increases as their ability to create and manage mathematics based on their own knowledge increases. The author adds that pupils may “reorganize and construct increasingly sophisticated mathematical understandings ... [when applying a constructivist method because they] ... participate in and contribute to the evolving classroom mathematical practices” (p. 189).

The findings of this study indicate that some of the younger participants prefer to follow the teacher's directions when doing mathematical tasks using the Bee-Bot and that

they would seek the aid of the teacher if they run into any difficulties. On the other hand, a number of younger participants prefer to learn how to programme the Bee-Bot for the specific mathematical task at hand by experimentation or by following the instructions provided by the Bee-Bot. One of the minor participants (Bob) claimed that he enjoys the challenge of coming up with a solution by applying critical thinking. Based on these findings, it appears that some pupils do not feel confident enough to experiment, while others are aware that the Bee-Bot provides them with the opportunity to explore and experiment with new ideas and concepts.

According to Dewey (1986), rather than just acquiring knowledge from the teacher, pupils should be involved in their own intellectual evaluation. Similarly, Papert (1993) states that learning is most effective when students have the most input in their own education. For their part, Kiong and Yong (2001) also point out that teachers must take on a more facilitating role in helping students build their own mathematical structures. According to Gatt (2015, p. 104):

ICT can empower teachers and learners by shifting teaching and learning processes from being highly teacher-dominated to student-centred. This transformation will result in increased learning gains for students, creating and allowing for opportunities for learners to develop their creativity, problem-solving abilities, informational reasoning skills, communication skills, and other higher-order thinking skills.

5.2.5 Using the Bee-Bot in the Classroom: Laying Stronger Foundations

Camilleri (2018) says that technology seems to pique a child's interest in learning and motivate him or her to retain what s/he learns. The findings of this research point to the fact that students would not perform to their full potential if they do not feel intrinsically motivated to do so on their own. Technology integration, according to Spector et al. (2016), may keep students interested and improve efficiency, adding that, using smart and technological tools “tend[s] to sustain interest and engagement” (p. 60). This is consistent with the claims of two educators (Janice and Jane) who participated in the study that the Bee-Bot keeps pupils interested because it is a movable technological device that assists pupils in achieving their goals, while making learning enjoyable for them. Students would memorise more what they learn about mathematics when they are intrinsically motivated to do so by the Bee-Bot.

According to Hunsaker (2018), robots bridge the virtual and physical worlds, thus facilitating the link between coding and the real world. Meanwhile, Catlin and Blamires (2010) claim that, with educational robots, students may apply what they have learned in the real world through specialised educational activities, challenging them to think, cultivating new abilities, or offering hands-on experience. Similarly, Niess et al. (2009) assert that ISTE¹⁶ has challenged educators to consider the emerging technological skills and competencies children need in today's technology-based economy. This study's findings, along with the findings of other studies, suggest that, teaching pupils the skills that they can

¹⁶ ISTE stands for International Society for Technology and Education.

apply in their everyday lives through the utilisation of the Bee-Bot has the potential to assist them in becoming more self-sufficient and independent.

Using educational robots, children may “learn to think creatively, plan systematically, analyse critically, and communicate effectively” (Cutajar, 2019, p. 25) — all critical skills for comprehending mathematics. Students' early mathematical development, according to Cicconi (2014), depends on their ability to work together, adding that early childhood educators may utilise technology to improve student interaction and group work. The findings of this study lend credence to the hypothesis that, having students work together on tasks can help them develop better social and communication skills. According to the findings, working together in groups can help pupils improve their ability to interact and connect with one another, in addition to giving them practice with teamwork skills, which are essential for the learning of mathematics.

Meanwhile, Lam et al. (2021) claim that technology-enhanced learning helps teachers build educational methods that are tailored to each student's requirements. Indeed, it transpired from this study that teachers implement a myriad of learning strategies in the classroom, one of which is the utilisation of technological tools. Tang et al. (2020) state that, using educational robotics to simulate real-world settings can “develop their intellectual and problem-solving capacities through self-exploration of real-world situations” (p. 1281) since educational robotics tasks “are highly-interactive and challenging” (p. 1278). Meanwhile, Lathifah et al. (2019) believe that, by emphasising the students' ability to be creative problem solvers, robots in the classroom can improve student learning. Students who use the Bee-Bot to solve mathematical problems are expected, according to the findings of this study, to take charge of their mathematical learning process. The students'

ability to solve problems is improved by using the Bee-Bot, thus offering them more control over their own educational experience.

Highfield and Mulligan (2008) propose that young children may be exposed to challenging mathematical thinking through technology such as the Bee-Bot, as demonstrated by the CRiMSE design research. In Ioannou et al.'s (2018) study, the teachers acknowledged that, after using the Bee-Bot to teach road safety, they could instantly think of math topics to expand on using the "Bee-Bot, such as for example, using a mat with shapes, numbers, and symbols for addition, subtraction, multiplication, and division in math" (p. 545). These reasons are reminiscent of this study's findings that pupils are exposed to a greater range of mathematical topics using the Bee-Bot, suggesting that pupils could pick up on a number of mathematical concepts simply by engaging with the Bee-Bot, regardless of whether or not this was the objective of the activity. Furthermore, it transpired from this research that, using the Bee-Bot facilitates educators' progression to the next mathematical concept. This could be attributed to the fact that one can utilise a high level of creativity while incorporating the Bee-Bot into mathematics activities.

According to McLoughlin (1999), technology can help pupils enhance their cognitive growth and skills, adding that scaffolding in technology-enhanced learning settings has broadened to encompass many types of support while boosting student responsibility. Similarly, Cameron (2015) claims that technology scaffolds and supports students' learning outside of the classroom. Likewise, the findings of this study imply that educators can make use of the Bee-Bot to scaffold and extend mathematics teaching and learning, as well as to reinforce learning.

5.2.5.1 Experiential Learning

The educators who participated in this study emphasised the need for experimentation for understanding and learning. This study shows that, while it is important for students to follow the instructions provided by the Bee-Bot, they should also be encouraged to experiment with the device on their own. According to the findings, students are more likely to become interested in a topic through experiential learning and the Bee-Bot provides students with the opportunity to investigate their own learning. Students would prefer to learn on their own at home, rather than in a traditional classroom setting, if they are not given the opportunity to experiment with their education at an early age. Therefore, it is possible to see that the Bee-Bot facilitates experiential learning thereby leading to creativity and exploration.

It further transpired that it is possible that pupils would not get it right on the very first attempt; nevertheless, this should not be a cause for concern and teachers should instead encourage their pupils to discover the solution through experimentation. This is consistent with the views of McRobbie and Tobin (1997), who state that one of the most important duties of a teacher is to shape pupils' experiential reality, "and providing opportunities for students to bring forward their extant knowledge in a process of making sense" (pp. 201-202). This is also reminiscent of Catlin and Blamires (2010) that, to be effective, educational robots must get students actively engaged in targeted learning activities and give them real-world experience. According to Piaget's (1952) cognitive development theory, individuals must construct their own meaning from experience.

The findings of this research indicate that pupils can engage in cooperative learning by utilising the Bee-Bot since, as they take turns and wait their turn to programme the Bee-

Bot, they discuss the many different coding options that are available to them. Pupils would thus be able to put their computational, analytic, and critical thinking skills to work as a result of the effort they put into discovering different coding options. Indeed, Cicconi (2014) argues that early childhood educators must use “technology to engage students in collaborative endeavors ... [that] ... deepens their understanding of math concepts” (p. 64) through teamwork. This indeed echoes Ioannou et al. (2018), who maintain that educational robotics can help students develop cognitive and collaborative skills. It is also consistent with Lee et al.’s (2013) claim that children with an unstructured curriculum have more time to explore and are more willing to share what they learn with their peers since they do not have to try “to complete specific activities, tasks, or challenges each day” (p. 277).

According to the study’s findings, the younger participants had fun participating in activities that were connected to the Bee-Bot. In fact, one of the younger participants (Stella) was able to describe a Bee-Bot game where they utilised flashcards throughout the activity. Meanwhile, another student (Pam) was able to explain the classroom arrangement for the Bee-Bot activity that was used in another activity. Moreover, one of the participants (Ruth) noted that, in order for the pupils to successfully use the Bee-Bot, they were required to take turns playing with it. The pupils were able to remember and recount events that took place when they participated in activities using the Bee-Bot, thus lending more support to the notion that students enjoy making use of the Bee-Bot.

Similarly, for O'Hara (2008), by incorporating technology into the classroom, "play is thought to be expanded and enhanced" (p. 30). Comparably, Beraza et al. (2010) claim that children consider robotics as a form of play, and thus, they learn programming and how to programme a robot. According to Lee et al. (2013), in an atmosphere where children have

the freedom to play and learn while utilising technology rather than in a more traditional classroom setting, strong social attachments can be more easily formed.

It further transpired from this research that the teacher supplied the pupils with instructions on how to use the Bee-Bot. According to Camilleri (2018), teachers should help their students to use a variety of educational technologies. Indeed, the results of this research indicate that pupils need to pay attention, comprehend the instructions, and then follow them when using the Bee-Bot. The study also indicates that, if students use the Bee-Bot in accordance with the instructions and follow the step process, they would be able to acquire a new mathematical skill. Cervera et al. (2020) explain that one can communicate with a Bee-Bot through coding commands, like the mathematical notions left, right, forward, and backward.

According to the findings of this research, the most significant barrier that stands in the way of the successful implementation of technology is the attitude of individuals. The findings demonstrate that those who are in charge of the pupils' education should be willing to step out of their comfort zone in order to understand the efficacy of technology in the classroom and how it can be used to teach and learn. Meanwhile, teachers should recognise that there are technological tools available and should then put such devices to work for the benefit of their students.

The findings emphasise greatly the significance of the utilisation of digital technologies by pupils in order to acquire the requisite abilities. It is indeed the responsibility of the teacher to ensure that each pupil becomes familiar with and proficient in the use of digital devices. Drijvers (2015) argues that "a process of professional

development is required” (p. 148) for educators, and it should focus on expanding both the teachers' technological expertise and their understanding of how to effectively use those skills in the classroom.

5.2.5.2 The Practice of Adapting Teaching to Each Individual Pupil

According to the findings of the study, the ergonomically designed Bee-Bot engages the pupils' senses through its combination of light, sound, and motion, while providing pupils with tangible learning experiences. The findings further indicate that, providing pupils with the option to disable the audio feature of the Bee-Bot is an excellent way to make the educational tool accessible to pupils who prefer to learn in this manner. Since it has a wide range of customisable functions, the Bee-Bot can accommodate a wide variety of pupils' needs.

One adult participant (Oscar) also brought up the possibility that the Bee-Bot mat may be made more visually appealing and suitable for use by individuals who are visual learners by providing an option for the user to personalise the mat by adding a selection of colours or graphics. The findings show that visual learners can grasp or expand their understanding of mathematical concepts through a Bee-Bot activity, even if the teacher's explanation is not fully understood. Spinarova and Vachalova (2021) assert that the Bee-Bot helps visually impaired students learn reasoning, mathematics, and spatial skills. This was also identified by Schina et al. (2021), who discovered that children with attention deficit disorder and dyslexia were achieving success in Bee-Bot tasks, and this “boosted their self-confidence and gave them a feeling of achievement” (p. 8).

According to the study's results, the utilisation of the Bee-Bot by teachers may be beneficial since it enables them to provide pupils with as many examples of a mathematical concept as they require to properly understand it. This research also found that teachers need to evaluate their students' progress and determine whether or not more explanation is necessary while their students are using the Bee-Bot to practise a mathematical technique. Similarly, Dalby & Swan (2019) suggest that technology can improve mathematics learning by enabling more comprehensive formative assessment methods. Niess et al. (2009) make the same claim, affirming that technology enables teachers to assess students' mathematical understanding, evaluate outcomes, and share what they would have learnt. Meanwhile, Cameron (2015) found that one teacher had employed the Bee-Bot and other forms of educational technology in the classroom "to scaffold for children" (p. 35) and assess student progress.

This research further provides specific information about different methods by which pupils who are unable to speak may still communicate and be successful with the assistance of digital technology. Indeed, it transpired that the pupils were less anxious when using the Bee-Bot and the teacher noticed that pupils had a greater interest in class since they could collaborate on a task with their classmates without the need to rely on in-depth explanations of their thought processes. The findings further demonstrate that, using the Bee-Bot to evaluate non-verbal pupils is advantageous since it enables teachers to assess the pupils' improvement and their requirements while they are working on practice tasks. Similarly, for Chaldi and Mantzanidou (2021), children on the autism spectrum can benefit from educational robots "to improve communicational skills" (p. 161), adding that the Bee-Bot boosts student engagement and participation, as opposed to traditional teaching approaches.

The outcomes of this study highlight that, when the pupils used the Bee-Bot, they were more involved in the learning process, and their teachers put in less effort to hold their attention. Spector et al. (2016) similarly state that “intelligent and adaptive technologies tend to sustain [pupils’] interest and engagement” (p. 60). Using the Bee-Bot to learn mathematics, the results of the current study show that no student would ever be at a disadvantage. According to Lombardi Calleja and Trapani Maggi (2021), using robots in mathematics makes it a subject that students can relate to and use critical thinking and problem-solving skills to better grasp the subject.

5.2.6 Measuring Students' Progress in Mathematics with the Bee-Bot

The findings of this research indicate strongly that the Bee-Bot can serve as a useful evaluation tool for determining whether or not pupils have achieved mastery of certain mathematical concepts. This research also brought to light the fact that, utilising the Bee-Bot contributes to an increase in the students’ sense of success and pride in themselves as a direct outcome of their achievements. According to the suggested Mathematics Teacher TPACK, teachers may utilise technology to correctly measure and convey students' mathematical understanding (Niess et al., 2009). For their part, Dalby and Swan (2019) argue that, using technology in mathematics classrooms allows for the development of more thorough forms of formative assessment thereby improving student learning. Additionally, Cameron (2015) found that technology can offer “scaffolding and reinforcement to children of different abilities” (p. 81).

According to the findings of this study, the Bee-Bot has the potential to be used in the evaluation of a variety of mathematical fields, including position and capacity. Highfield et al. (2008) maintain that, when children use the Bee-Bot, they are more engaged, thus

helping them to grasp “mathematical concepts ... [well] ... particularly transformation and measurement processes much earlier than traditionally expected” (p. 175). Similarly, Kritzer and Green (2021) state that digital devices like the Bee-Bot allow for the tactile investigation of fundamental mathematics concepts, and pupils “can code the Bee-Bot as they explore numeration, distance, direction, estimation, sequencing, and coding concepts” (p. 422). The authors add that the Bee-Bot and other similar robots can assist very young children in getting a head start on learning STEM subjects like coding, pattern recognition, and problem solving.

This study’s findings demonstrate that the Bee-Bot can help teachers maintain an up-to-date understanding of their students, determine whether any educational gaps exist among their pupils, and modify the instructional practices currently in place, thus addressing more effectively the requirements of individual pupils. Similarly, Kaplan (2017) argues that, by utilising various technological tools, educators may better understand their pupils' varying requirements. Correspondingly, Lam et al. (2021) state that the goal of technology-enhanced learning is to help teachers create a range of teaching materials that meet the unique requirements of each student, and digital “technology could give teachers a greater flexibility to design a more interactive learning environment and to make the learning process more engaging” (p. 93).

5.2.7 Developing the Ability to Think Critically Through Programming a Bee-Bot

The younger participants opine that the Bee-Bot facilitates their acquisition of more mathematical knowledge and is simple to use, which may be attributed to the fact that it provides more than one possible answer. Mathematicians like Papert (1980) feel that children can gain direct access to some of mathematics' most fundamental principles

through programming. Citing Jean Piaget's genetic epistemology, Papert (1980) thinks that young children continually mine and synthesise mathematical information from their surroundings and their bodies' connections to them. According to Messer et al.'s (2018) findings, children "carrying out and learning simple programming will increase mathematical abilities and spatial awareness" (p. 2886).

The findings of this study suggest that, providing students with the opportunity to learn how to programme a Bee-Bot can assist in the development of their analytical and logical reasoning skills. Havlásková et al. (2019) share these views, arguing that the Bee-Bot is engaging and useful "for developing logical thinking, spatial imagination, planning and pre-mathematical concepts" (p. 202). It further transpired that, providing learners with access to the Bee-Bot would have a favourable effect on the pupils' capacity for critical thinking and their potential to learn new cognitive talents. McLoughlin (1999) and Mikropoulos and Bellou (2013) agree that technology can assist students in developing their cognition and abilities.

Similarly, Papert (1980) suggests that "computational technology and computational ideas can provide children with new possibilities for learning, thinking, and growing emotionally as well as cognitively" (pp. 17-18). Furthermore, Ioannou et al. (2018) assert that "educational robotics should be considered broadly, as a tool that can support the development of a variety of skills, including cognitive skills, personal development, and collaboration skills" (p. 538), while Hoyles and Noss (2003) argue that problem-solving and abstract thinking are crucial cognitive processes in mathematics education.

This research suggests that, exposing pupils to mathematical problems through the use of the Bee-Bot helps them understand that there are several ways to approach the

solution to any given mathematical challenge. According to the findings, one of the most effective methods to make use of the Bee-Bot to encourage and enhance students' critical thinking is to adjust questioning tactics in line with the nature of the activity that is currently being completed. In addition, a teacher is able to modify the level of difficulty of the questions based on the students' unique capabilities and the areas in which they need to improve.

Lathifah et al. (2019) argue that, incorporating robotics into the teaching process enables pupils to relate to real-world problems. Similarly, Tang et al. (2020) believe that, using educational robotics to simulate real-world settings can improve pupils' "intellectual and problem-solving capacities through self-exploration of real-world situations" (p. 1281). In line with the findings of this study, Cutajar (2019) argues that, when pupils are involved in activities that need computational thinking abilities and problem-solving skills from a young age, problem-solving becomes easier for them. Additionally, Cervera et al. (2020) contend that pupils may enhance their ability to solve mathematical problems by participating in computing-related tasks while in the classroom.

The findings further indicate that, having pupils work together to solve problems and engage in conversation with one another when utilising the Bee-Bot in the classroom is an effective way to foster these behaviours. The findings also reveal that pupils would answer questions on the challenges that they were working on in teams, hence motivating them to utilise critical thinking when they are working together. For instance, Cutajar (2019) asserts that students can improve their critical thinking skills and teamwork abilities by being exposed to real-life situations. According to Alimisis et al. (2007), technological

advancements allow for the development of classroom settings that promote student collaboration and discussion.

Similarly, Cicconi (2014) proposes that teachers of young children can use technology to enhance group work, adding that the use of educational robotics helps pupils develop three crucial abilities, one of which is the ability to work together effectively, which, as some of the adult participants explained, is very useful while learning mathematical concepts. Furthermore, according to Casler-Failing (2018), “the collaborative nature of robotics provides a context for learning in mathematics that could be limitless” (p. 20).

5.2.8 Assessment of Mathematical Abilities by the Bee-Bot Across Genders

According to the outcomes of this study, there is no difference in the level of benefit that male or female pupils receive from utilising the Bee-Bot in the classroom. This finding is supported by the literature. For example, Mondada et al. (2017) observe that robot-building kits come in gender-neutral hues and their software is built for both boys and girls. The findings highlight the importance of incorporating suitable visuals in the Bee-Bot tasks because, if students are not engaged or motivated by the content, they would not put in the effort required to learn it. According to Angeli & Valanides (2020, p. 10) “a developmentally-appropriate gender-friendly robotics learning environment will allow both boys and girls to experience a positive flow of experience, and to endure and persevere in learning”. This research also supports this observation.

Meanwhile, Gribbins et al.’s (2007) study found that

“females tend to show more interest in collaborative and group learning. They also prefer to learn in a more social setting. Males, on the other hand, exhibit more

tendency to prefer independent learning situations rather than collaborative” (p. 744).

However, although the authors claim that there is a difference between gender preferences when working independently or in a team, according to the findings of this study, most of the minor participants, regardless of gender, showed a preference for working in a group when engaged in a Bee-Bot activity. Indeed, one of the younger participants (Ruth) feels sad at the prospect of working alone and another participant (Bob) loathes the idea. Meanwhile, another younger participant, John, mentioned that, taking turns using the robot during an activity is one of his favourite moments when taking part in the Bee-Bot tasks.

According to the findings, pupils are evaluated in mathematics not according to their gender, but rather, on the basis of their own mathematical skills and how they learn best. Urlings et al. (2019) found that the Bee-Bot activities had the same effect on boys’ and girls’ thinking time, while Papadakis and Kalogiannakis (2020) found no gender differences in early computational thinking and coding among five- to six-year-olds using the Bee-Bots.

One of the younger participants of this study (Lara) recalled an experience she had with the Bee-Bot and which she enjoyed, where she played a game called ‘Hide and Seek’ that involved the Bee-Bot. The Bee-Bot and other forms of robotic-assisted instruction are cited by Yang et al. (2020) as potential means of bridging the achievement gap between male and female pupils, adding that “[a] gender-friendly robotic learning environment suitable for student development will enable both boys and girls to experience a positive experience flow and keep learning” (p. 629). However, they argue that additional research is

needed to determine whether there is a difference in gaining knowledge with the Bee-Bot based on the gender of a person.

5.2.9 Preparing and Supporting Teachers

According to the findings of this study, most educators are already familiar with the Bee-Bot and use it in class. It transpired that teachers learnt how to operate the Bee-Bot by watching educational videos on YouTube, practising with the robot in the classroom, receiving feedback from support teachers and experimenting on their own. However, Drijvers (2015) suggests that teachers should expand their knowledge of educational technology and pedagogical material. According to Dalby and Swan (2019), “[f]or pedagogical change to be achieved ... it seems that a better understanding of how technology contributes to effective learning processes is still required” (p. 832).

Meanwhile, according to Gatt (2015), one of the first moves towards incorporating technology in Malta's classrooms was giving laptops to all teachers. The author also notes that this move was supported by the provision of teacher training and the establishment of the e-Learning Department within the Directorate for Quality and Standards in Education. According to this study, teachers who require assistance with digital devices can turn to support teachers from the Directorate for Digital Literacy and Transversal Skills, who, according to the adult interviewees, were easily available.

The classroom teacher, indeed, receives assistance from the support teacher in the form of the development of Bee-Bot-based activities, and sometimes the support teacher even organises a lesson with the classroom teacher. The findings also highlight the fact that

teachers are given assistance in implementing the Bee-Bot activities for mathematics teaching and learning.

This study further found that parents of pupils in the Early Years could benefit from training on how to effectively support their children's use of online educational resources such as the Bee-Bot and other technological tools that are accessible at school. This viewpoint is supported by Mauk, Willett and Coulter (2020), who claim “that parents and caregivers are responsible for getting their children interested in coding” (p. 400).

Based on the findings, it appears that the educator could be concerned about the amount of time required to set up the essential resources before using the Bee-Bot in the classroom. Despite a participant teacher's (Maria) valid concerns, according to another educator (Oscar), the vast majority of the necessary materials can be obtained with little effort and require almost no prior planning. According to Catlin and Blamires (2010), for teachers to consider using robots like the Bee-Bot, they must believe that their benefit outweighs preparation time.

According to the findings, the assistant headteacher at the school involved in this study actively supports and values the teachers' use of technology in the classroom. Indeed, Scicluna (2020, p. 5) insists that schools need

leaders who are aware of what digital leadership entails, who quickly identify the signs of the time and propose workable solutions, and who model resiliency and empower others to use technology to their advantage to make sure that no one is caught unprepared again.

5.3 Conclusion

It can be concluded from this research that the Bee-Bot is an excellent tool for both the teaching and learning of mathematics since the teacher may reach out to pupils with a variety of learning styles and skills by including this device in mathematical tasks. The Bee-Bot encourages 21st-century skills, including computational and critical thinking, communication, and collaboration. This study further reveals that pupils enjoy using technology and that the Bee-Bot stimulates them, engages them in learning, and helps them comprehend mathematical concepts. This research found that the Bee-Bot can help teachers assess pupils' mathematics understanding by allowing them to observe pupils' hands-on activities and provide timely feedback.

Nonetheless, some teachers are still hesitant to utilise the Bee-Bot in their classrooms because they are concerned about the substantial amount of planning and preparation work required for successful Bee-Bot activities. According to the results of this investigation, it is safe to conclude that the belief that digital devices are time-wasting toys is still widely held. This can be deduced from the fact that some of the younger participants voiced their opposition to the use of the Bee-Bots in the classroom. Parents and carers who are responsible for the care of young children should be well-versed in the usefulness of technological devices that can aid in the development of critical skills necessary for democratic participation and employment in the workforce.

Chapter 6

CONCLUSION

6.1 Introduction

This final chapter goes over and explains the advantages and disadvantages of this study, presents a brief overview of the salient findings, provides some recommendations for future research, and concludes with some final thoughts.

6.2 Potential Benefits and Limitations of the Research

The strength of this case-study resides in its epistemological underpinning. It used a constructivist method to data collection from the research participants and an inductive interpretation of the findings. Through a grounded theory approach, this researcher was able to probe the participants further with questions that brought forth their own experiences and insights, as Charmaz (2006) contends. This was intended to contribute to the readers' understanding by shining a light on how the use of digital tools, specifically the Bee-Bot, has altered traditional approaches to evaluating students' proficiency in mathematics (National Research Council et al., 1989), particularly in the Maltese school setting, where very little research had hitherto been conducted.

This research also indicates that, as stated by Caballero-González et al. (2019), the students' views on the value of mathematical learning using technological tasks, involving the Bee-Bot, allow them “to strengthen their mental processes of critical thinking and spatial disposition” (p. 22). The focus group meetings were organised at times during the school day after consultation with the Head of School and the teachers to ensure as little disturbance to the school day as possible. It was also considered that, while the pupils were

participating in focus group sessions, they were only likely to be missing information that their teacher could go over with them individually.

However, there are limitations to this study, most notably the limited sample size and sampling techniques. This research was limited due to the time constraints imposed by the demands of the course. The researcher, unlike more extensive grounded theory investigations, used convenience and purposive sampling, rather than theoretical sampling that required a longer and more sustained iterative approach.

The fact that this research was conducted mostly among educators in State Primary schools was also a limitation. This is a case-study that cannot be generalisable. Another key limitation is that this researcher had to interview the young and old participants in their native language, and then translated the gathered data into English. Consequently, nuances and subtle declarations could have been lost in translation.

Comparing the transcribed versions of the interviews to the original recordings was one of the tasks that this researcher was responsible for to ensure that all the data and transcriptions were accurate. Meanwhile, this researcher's values and bias may have distorted data gathering, translation, initial coding, memoing, and analysis.

6.3 The Study's Major Findings

The primary goal of this research was to learn more about how the Bee-Bot contributes to the assessment of mathematical concepts. These findings provide insight into an Education Officer's, Year One teachers', and some Year One pupils' perspectives on the role of the Bee-Bot in engaging pupils during mathematical tasks. Similar to the study by Highfield (2010), this grounded investigation outlines how the Bee-Bot makes the learning

and teaching of mathematical concepts more interesting and accessible. The study drew the subsequent conclusions:

- The pupils disclosed that they had been taught how to utilise the Bee-Bot by their teachers. It transpired that pupils enjoy the Bee-Bot-integrated activities that can expose them to a broader range of mathematical concepts, as opposed to traditional approaches. Echoing Lathifah et al. (2019), it was established that using the Bee-Bot to learn mathematics is akin to playing a game, thus enhancing students' motivation since the Bee-Bot encourages experiential learning. The pupils recalled positive Bee-Bot-integrated activities. According to this study, using the Bee-Bot to teach practical, transferrable skills may help pupils become more self-reliant and autonomous (Mikropoulos & Bellou, 2013). According to Spector et al. (2016), and as also suggested through all the adult participants' personal experiences, using technology in the classroom enhances student engagement.
- According to Cameron's (2015) research and considering this study's findings, the Bee-Bot can be used by teachers to scaffold and enhance their pupils' verbal and non-verbal mathematical education, assess pupils' development, identify whether they require more help, and adapt feedback and teaching. The Bee-Bot helps pupils who learn visually to grasp and apply mathematical concepts, even if they initially do not understand the explanation. This was also confirmed in Lopez-Caudana et al.'s (2020) study. The findings show that the Bee-Bot may help non-verbal students to interact, participate, and succeed without fear (Chaldi & Mantzanidou, 2021). It further transpired that the Bee-Bot's immediate math activities make formative assessments simpler and instant. Meanwhile, with the Bee-

Bot, a teacher may conduct formative assessment in several mathematical areas.

According to the findings, the Bee-Bot is gender-neutral, as Mondada et al.'s (2017) investigation also concluded, and does not influence the academic achievement of boys versus girls (or vice versa).

- The findings demonstrate that the Bee-Bot encourages pupils to collaborate and think critically, as also noted by Cicconi (2014) and Ioannou et al. (2018). This study also confirms the conclusion reached by Highfield (2010) that the Bee-Bot helps pupils to understand that there are several pathways to a solution in mathematics. According to the findings, teaching pupils how to programme the Bee-Bot can help them become more strategic thinkers by requiring them to plan carefully (Papert, 1980; Havlásková et al., 2019; McLoughlin, 1999; Mikropoulos & Bellou, 2013). The adults in this study agreed that, giving pupils access to the Bee-Bot helps them focus and develop crucial computational skills (Papert, 1980). The findings further demonstrate that some pupils prefer to follow their teacher's lead while working with the Bee-Bot, while others prefer more freedom in approaching mathematical challenges and the Bee-Bot programming.
- It transpired that the Bee-Bot allows pupils to work in groups, thus enabling them to practise teamwork and improve their interaction and collaboration skills, as also established by Cicconi (2014). This study also confirms that the Bee-Bot, incorporated into classroom activities, can be very beneficial, although there is a potential situation wherein pupils may have a hard time waiting for their turn. This notwithstanding, according to the findings, the great majority of pupils, regardless of gender, prefer group work, with one pupil identifying taking turns as a means of collaboration.

- Some points to consider include the fact that the teacher needs to exercise caution when choosing the lesson's theme as the assessment for the pupils' mathematical learning might be jeopardised if they are not interested in the theme. Another aspect that needs to be taken into consideration is that pupils' learning and its assessment are affected by the learning setting due to the possible environmental distractions for both pupils and teachers.
- According to the findings and as similarly noted by Spinarova and Vachalova (2021), Schina et al. (2021), and Lopez-Caudana et al. (2020), even though the Bee-Bot is effective in accommodating a variety of learning styles, its success depends on the teacher's approach to implementing it as a learning tool. The findings indicate that a teacher could be reluctant to use the Bee-Bot because of concerns that it would add too much preparation time. It has been stated that the vastness of today's curricula leaves little time for teachers to develop lesson plans that incorporate the Bee-Bot.
- The findings show that teachers would benefit from training and curricular time to share and learn from one another. The Directorate for Digital Literacy and Transversal Skills, according to an educator, aids with digital devices through support teachers who are present in schools regularly (Gatt, 2015). The adult interviewees also noted that the support offered by Learning Support Educators and by the Senior Leadership Team is essential for the successful completion of Bee-Bot tasks.
- A few pupil participants voiced their disapproval of learning with the Bee-Bot because they perceive it more as a toy than a tool for learning. An educator remarked that parents ought to be also aware of how the Bee-Bot is used and its significance in the development of a wide range of competencies.

In general, educators view the Bee-Bot as an effective tool for learning mathematical concepts and for formative assessment. The pupils look forward to utilising the Bee-Bot since it enables them to collaborate with their classmates (Ioannou et al., 2018) and to find solutions to mathematical problems.

6.4 Future Research Recommendations

Future research can investigate how the existing collaboration between the class teacher and support teacher in the Bee-Bot's integration in mathematics lessons can be enhanced so that educators have a better understanding of how to incorporate the Bee-Bot effectively in the formative assessment process. This research would shed light on what classroom teachers and support teachers alike value most when integrating innovative technology into teaching mathematics and conducting its formative assessments.

This study has the potential to pave the way for further research into the Senior Leadership Team's understanding of the efficacy of the Bee-Bot in the classroom setting for the teaching and learning of mathematics. This research would assist in identifying knowledge gaps where further training is required to promote the Bee-Bot's integration.

Future research can investigate the perspectives of parents of young children on the effectiveness of the Bee-Bot in helping their children learn and comprehend mathematical concepts. This would provide insight into how parents regard the incorporation of the Bee-Bot into the mathematical curriculum and how their perspectives influence their children.

Larger studies, perhaps using a quantitative approach based on themes identified in this research, should make the conclusions more generalisable. Studies with larger and

nationwide samples can investigate the benefits and challenges of the Bee-Bot as an assessment tool in the teaching and learning of mathematical concepts.

6.5 A Closing Remark

This study found that pupils in today's schools have more access to digital resources that help them grow academically as Spector et al. (2016) had already noticed, while also honing the critical thinking and problem-solving abilities essential at the modern workplace. As Cutajar (2019) suggests, pupils may utilise digital devices to acquire and enhance vital skills, such as, creativity. Indeed, digital technologies may contribute to the holistic development of each child. As concluded by Spiteri and Chang Rundgren (2017), nowadays, educators understand the value of incorporating technological tools and the vast majority of them actively seek out opportunities to do so.

This study has provided this researcher with many personal and professional insights. She finds this writing to be beneficial and significant, as this University Degree was a great opportunity for this researcher to improve her capacity to think critically, assess information, convey findings, and reflect on her own and others' perspectives. This researcher sought to integrate research findings with pre-existing theory and literature as a clear demonstration of how this study's investigation offers a theoretical contribution, as suggested by Birks et al. (2009). Meanwhile, this researcher employed a storyline approach to explain the theoretical outcomes of her study in a compelling and distinctive manner, "without diminishing the credibility, validity or merit of [her] work" (Birks et al., 2009, p. 416).

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APPENDIX 1: FREC Ethics Approval



Faculty of Education

University of Malta
Msida MSD 2080, Malta

Tel: +356 2340 3058/2932
educ@um.edu.mt

www.um.edu.mt/educ

7th January 2022

RE: Application for Research Ethics Clearance 9215_03092021_Sue Ellen Gambin

Dear Sue Ellen Gambin,

With reference to your application 9215_03092021_Sue Ellen Gambin for Research Ethics clearance, I am pleased to inform you that **FREC finds no ethical or data protection issues in terms of content and procedure.**

You may therefore proceed to approach potential informants to collect data using the tools/documents outlined in this application.

You are reminded that it is your responsibility - under the guidance of your supervisor - to distribute Information Letters and Consent/Assent Forms that are written in appropriate and correct English and Maltese.

Yours sincerely

A handwritten signature in black ink, appearing to read "J Gravina".

Dr Joseph Gravina
Chairperson Faculty Research Ethics Committee
Faculty of Education

APPENDIX 2: Permission to Carry Out Research with the Education Officer



GOVERNMENT OF MALTA
MINISTRY FOR EDUCATION
DIRECTORATE FOR RESEARCH, LIFELONG
LEARNING AND EMPLOYABILITY

Tel: 25982743

researchandinnovation@ilearn.edu.mt

PERMISSION TO CONDUCT RESEARCH STUDY

Date: 25th October 2021

Ref: R10-2021 951

To: Director, Directorate for Learning and Assessment Programmes (EO Mathematics)

From: Director

Title of Research Study: *The Bee-Bot in the assessment for learning of mathematical concepts.*

The Directorate for Research, Lifelong Learning and Employability would like to inform that approval is granted to **Sue Ellen Gambin** to conduct the research in State Schools according to the official rules and regulations, subject to approval from the Ethics Committee of the respective Higher Educational Institution.

The researcher is committed to comply with the General Data Protection Regulation (GDPR) and will ensure that these requirements are followed in the conduct of this research. The researcher will be sending letters with clear information about the research, as well as consent forms to all data subjects and their parents/guardians when minors are involved. Consent forms should be signed in all cases particularly for the participation of minors in research.

For further details about our policy for research in schools, kindly visit www.research.gov.mt.

Thank you for your attention and cooperation.

Claire Mamo

MA Ed (Open)
Research Support Teacher
Directorate for Research, Lifelong Learning and Employability

f/ Alex Farrugia

Director
Directorate for Research, Lifelong Learning and Employability
Great Siege Road | Floriana | VLT 2000

t: +356 25982443 e: alex.farrugia@gov.mt | www.education.gov.mt



MINISTRY FOR EDUCATION

APPENDIX 3: Permission to Carry Out Research with the Head of School



GOVERNMENT OF MALTA
MINISTRY FOR EDUCATION
DIRECTORATE FOR RESEARCH, LIFELONG
LEARNING AND EMPLOYABILITY

Tel: 25982743

researchandinnovation@ilearn.edu.mt

PERMISSION TO CONDUCT RESEARCH STUDY

Date: 25th October 2021

Ref: R10-2021 951

To: Head of College Network – SMC - (Zabbar Primary School A)

From: Director

Title of Research Study: *The Bee-Bot in the assessment for learning of mathematical concepts.*

The Directorate for Research, Lifelong Learning and Employability would like to inform that approval is granted to **Sue Ellen Gambin** to conduct the research in State Schools according to the official rules and regulations, subject to approval from the Ethics Committee of the respective Higher Educational Institution.

The researcher is committed to comply with the General Data Protection Regulation (GDPR) and will ensure that these requirements are followed in the conduct of this research. The researcher will be sending letters with clear information about the research, as well as consent forms to all data subjects and their parents/guardians when minors are involved. Consent forms should be signed in all cases particularly for the participation of minors in research.

For further details about our policy for research in schools, kindly visit www.research.gov.mt.

Thank you for your attention and cooperation.

Claire Mamo

MA Ed (Open)
Research Support Teacher
Directorate for Research, Lifelong Learning and Employability

f/ Alex Farrugia

Director
Directorate for Research, Lifelong Learning and Employability
Great Siege Road | Floriana | VLT 2000

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MINISTRY FOR EDUCATION

APPENDIX 4: Permission to Carry Out Research with Year One Teachers



GOVERNMENT OF MALTA
MINISTRY FOR EDUCATION
DIRECTORATE FOR RESEARCH, LIFELONG
LEARNING AND EMPLOYABILITY

Tel: 25982743

researchandinnovation@ilearn.edu.mt

PERMISSION TO CONDUCT RESEARCH STUDY

Date: 25th October 2021

Ref: R10-2021 951

To: Head of School – SMC Zabbar Primary School A

From: Director

Title of Research Study: *The Bee-Bot in the assessment for learning of mathematical concepts.*

The Directorate for Research, Lifelong Learning and Employability would like to inform that approval is granted to **Sue Ellen Gambin** to conduct the research in State Schools according to the official rules and regulations, subject to approval from the Ethics Committee of the respective Higher Educational Institution.

The researcher is committed to comply with the General Data Protection Regulation (GDPR) and will ensure that these requirements are followed in the conduct of this research. The researcher will be sending letters with clear information about the research, as well as consent forms to all data subjects and their parents/guardians when minors are involved. Consent forms should be signed in all cases particularly for the participation of minors in research.

For further details about our policy for research in schools, kindly visit www.research.gov.mt.

Thank you for your attention and cooperation.

Claire Mamo

MA Ed (Open)
Research Support Teacher
Directorate for Research, Lifelong Learning and Employability

f/ Alex Farrugia

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Great Siege Road | Floriana | VLT 2000

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MINISTRY FOR EDUCATION

APPENDIX 5: Permission Letter - Director

Mr. [REDACTED]
Director,
Directorate for Research, Lifelong Learning and Employability
Ministry for Education
Great Siege Road,
Floriana, VLT 2000

7th October 2021

Dear Mr. [REDACTED],

My name is Sue Ellen Gambin and I am a student at the University of Malta, presently reading for a Master of Education in e-Learning. I am presently conducting a research study for my dissertation titled "The Bee-Bot in the assessment for learning of mathematical concepts".

This study aims to explain and analyse educational leaders', educators', and students' perceptions of assessment for learning of mathematical concepts when utilising the Bee-Bot, while determining effective approaches in its use through the knowledge, beliefs, and experiences of the participants. This project is being conducted under the supervision of Dr. Joseph Vancell.

I am hereby seeking your permission to interview the Education Officer in charge at the Directorate for Digital Literacy and Transversal Skills, Dr. [REDACTED], Head of School at [REDACTED], three Year One teachers and twelve of their pupils. Adults will be interviewed in semi-structured audio-recorded interviews, and children will participate in focus groups. Participation will be entirely voluntary and participants will be free to withdraw at any point, without any repercussions. Data collected will be anonymised. Only my supervisor and myself will have access to this data.

Should you require further information, please do not hesitate to contact me or my supervisor. Both our contact details are provided below.

Thank you for your kind consideration of this request.

Sincerely,



Sue Ellen Gambin
[REDACTED]



Dr. Joseph Vancell
[REDACTED]

APPENDIX 6: Permission Letter – Head of College Network

Ms. [REDACTED]
Head of College Network
Office of the Principal,
[REDACTED]

6th June 2021

Dear Ms. [REDACTED],

My name is Sue Ellen Gambin and I am a student at the University of Malta, presently reading for a Master of Education in e-Learning. I am presently conducting a research study for my dissertation titled “The Bee-Bot in the assessment for learning of mathematical concepts”.

This study aims to explain and analyse educational leaders’, educators’, and students’ perceptions of assessment for learning of mathematical concepts when utilising the Bee-Bot, while determining effective approaches in its use through the knowledge, beliefs, and experiences of the participants. This project is being conducted under the supervision of Dr. Joseph Vancell.

I am hereby seeking your permission to interview the Head of School at [REDACTED], three Year One teachers and twelve of their pupils. Adults will be interviewed in semi-structured audio-recorded interviews, and children will participate in focus groups. Participation will be entirely voluntary and participants will be free to withdraw at any point, without any repercussions. Data collected will be anonymised. Only my supervisor and myself will have access to this data.

Should you require further information, please do not hesitate to contact me or my supervisor. Both our contact details are provided below.

Thank you for your kind consideration of this request.

Sincerely,



Sue Ellen Gambin
[REDACTED]



Dr. Joseph Vancell
[REDACTED]

APPENDIX 7: Permission Letter – Head of School

[REDACTED]

Head of School,

[REDACTED]

6th June 2021

Dear Mrs. [REDACTED],

My name is Sue Ellen Gambin and I am a student at the University of Malta, presently reading for a Master of Education in e-Learning. I am presently conducting a research study for my dissertation titled “The Bee-Bot in the assessment for learning of mathematical concepts”.

This study aims to explain and analyse educational leaders’, educators’, and students’ perceptions of assessment for learning of mathematical concepts when utilising the Bee-Bot, while determining effective approaches in its use through the knowledge, beliefs, and experiences of the participants. This project is being conducted under the supervision of Dr. Joseph Vancell.

I am hereby seeking your permission to interview three Year One teachers and twelve of their pupils. Adults will be interviewed in semi-structured audio-recorded interviews, and children will participate in focus groups. Participation will be entirely voluntary and participants will be free to withdraw at any point, without any repercussions. Data collected will be anonymised. Only my supervisor and myself will have access to this data.

Should you require further information, please do not hesitate to contact me or my supervisor; both our contact details are provided below.

Thank you for your kind consideration of this request.

Sincerely,



Sue Ellen Gambin

[REDACTED]



Dr. Joseph Vancell

[REDACTED]

APPENDIX 8: Information Letter – Education Officer and Head of School

Information letter

7th January 2022

Dear Sir/Madam,

This letter is an invitation for participation in a research study.

Study Overview

My name is Sue Ellen Gambin and I am a student at the University of Malta, presently reading for a Master of Education in e-Learning. I am presently conducting a research study for my dissertation titled “The Bee-Bot in the assessment for learning of mathematical concepts”; this is being supervised by Dr. Joseph Vancell of the Department of Leadership for Learning & Innovation. Below you will find information about the study and about what your involvement would entail, should you decide to take part.

The aim of the study is to explain and analyse educational leaders', educators', and students' perceptions of assessment for learning of mathematical concepts when utilising the Bee-Bot, while determining effective approaches in its use through the knowledge, beliefs, and experiences of the participants. Your participation in this study would help contribute to a better understanding of different views with regards to the use and effectiveness of the Bee-Bot when assessing learning of mathematics. Any data collected from this research will be used solely for purposes of this study.

Your Involvement

Should you choose to participate, you will be interviewed once. The interviews are to be conducted in a place and at a time that is convenient for you. Data collected will be anonymised and great care will be taken not to reveal your identity in the research. This notwithstanding, given your position as EO/Head of School, your anonymity cannot be fully guaranteed. The study will be available as a dissertation from the University of Malta’s library.

Participation in this study is entirely voluntary; in other words, you are free to accept or refuse to participate, without needing to give a reason. You are also free to withdraw from the study at any time, without needing to provide any explanation and without any negative repercussions for you. Should you choose to withdraw, any data collected from your interview will be stored anonymously.

If you choose to participate, please note that there are the following direct benefits to you. The participants will benefit from increased knowledge and better understanding of how the Bee-Bot can be used to assess learning of mathematical concepts and they will also benefit from increased awareness about the effectiveness of Bee-Bot-enhanced mathematical learning. Your participation does not entail any known or anticipated risks.

Please note also that, as a participant, you have the right under the General Data Protection Regulation (GDPR) and national legislation to access, rectify and where applicable ask for the data concerning you to be erased. All data collected will be stored in an anonymised form upon completion of the study.

A copy of this information sheet is being provided for you to keep and for future reference. Thank you for your time and consideration.

Contact Information

Should you have any questions or concerns, please do not hesitate to contact me by e-mail on [REDACTED]. You can also contact my supervisor over the phone: [REDACTED] or via email: [REDACTED].

I assure you that this study has been reviewed and received ethics clearance through the Research Ethics Committee, University of Malta. However, the final decision to participate is yours.

Thank you in advance.

Sincerely,



Sue Ellen Gambin

Email: [REDACTED]



Dr. Joseph Vancell

[REDACTED]
[REDACTED]

APPENDIX 9: Information Letter – Year One Teachers

Information letter

7th October 2021

Dear Sir/Madam,

This letter is an invitation for participation in a research study.

Study Overview

My name is Sue Ellen Gambin and I am a student at the University of Malta, presently reading for a Master of Education in e-Learning. I am presently conducting a research study for my dissertation titled “The Bee-Bot in the assessment for learning of mathematical concepts”; this is being supervised by Dr. Joseph Vancell of the Department of Leadership for Learning & Innovation. Below you will find information about the study and about what your involvement would entail, should you decide to take part.

The aim of the study is to explain and analyse educational leaders', educators', and students' perceptions of assessment for learning of mathematical concepts when utilising the Bee-Bot, while determining effective approaches in its use through the knowledge, beliefs, and experiences of the participants. Your participation in this study would help contribute to a better understanding of different views with regards to the use and effectiveness of the Bee-Bot when assessing learning of mathematics. Any data collected from this research will be used solely for purposes of this study.

Your Involvement

Should you choose to participate, you will be interviewed once. The interviews are to be conducted in a place and at a time that is convenient for you. Data collected will be anonymised so that the identity of the research subject is not revealed, and it will be available as a dissertation from the University of Malta’s library.

Participation in this study is entirely voluntary; in other words, you are free to accept or refuse to participate, without needing to give a reason. You are also free to withdraw from the study at any time, without needing to provide any explanation and without any negative repercussions for you. Should you choose to withdraw, any data collected from your interview will be stored anonymously.

If you choose to participate, please note that there are the following direct benefits to you. The participants will benefit from increased knowledge and better understanding of how the Bee-Bot can be used to assess learning of mathematical concepts and they will also benefit from increased awareness about the effectiveness of Bee-Bot-enhanced mathematical learning. Your participation does not entail any known or anticipated risks.

Please note also that, as a participant, you have the right under the General Data Protection Regulation (GDPR) and national legislation to access, rectify and where applicable ask for the data concerning you to be erased. All data collected will be stored in an anonymised form upon completion of the study.

A copy of this information sheet is being provided for you to keep and for future reference. Thank you for your time and consideration.

Contact Information

Should you have any questions or concerns, please do not hesitate to contact me by e-mail on [REDACTED]. You can also contact my supervisor over the phone: [REDACTED] or via email: [REDACTED].

I assure you that this study has been reviewed and received ethics clearance through the Research Ethics Committee, University of Malta. However, the final decision to participate is yours.

Thank you in advance.

Sincerely,



Sue Ellen Gambin

Email: [REDACTED]



Dr. Joseph Vancell

[REDACTED]
[REDACTED]

APPENDIX 10: Consent Form – Education Officer

Participant's Consent Form

Research title: The Bee-Bot in the assessment for learning of mathematical concepts

I, the undersigned, give my consent to take part in the study conducted by Sue Ellen Gambin. This consent form specifies the terms of my participation in this research study.

1. I have been given written and verbal information about the purpose of the study; I have had the opportunity to ask questions and any questions that I had were answered fully and to my satisfaction.
2. I also understand that I am free to accept to participate, or to refuse or stop participation at any time without giving any reason and without any penalty. Should I choose to participate, I may choose to decline to answer any questions asked. In the event that I choose to withdraw from the study, any data collected from me will be stored anonymously.
3. I understand that I have been invited to participate in interviews about the participants' perceptions of how assessment of learning of mathematical concepts is achieved using the Bee-Bot, while determining effective approaches in its' use through the knowledge, beliefs, and experiences of the participants. I am aware that the interviews will take approximately one scholastic term where I will be interviewed once or twice, according to the requirements of the research. I understand that the interview/s will to be conducted in a place and at a time that is convenient for me.
4. I understand that my participation does not entail any known or anticipated risks.
5. I understand that there are direct benefits to me that include increased knowledge and better understanding of how the Bee-Bot can be used to assess learning of mathematical concepts and increased awareness about the effectiveness of Bee-Bot-enhanced mathematical learning. I also understand that this research may benefit others by gathering knowledge of how the Bee-Bot is used to assess learning of mathematical concepts and its efficacy.
6. I understand that, under the General Data Protection Regulation (GDPR) and national legislation, I have the right to access, rectify, and where applicable, ask for the data concerning me to be erased.
7. I understand that all data collected will be stored in an anonymised form on completion of the study and following publication of results.

8. I have been provided with a copy of the information letter and understand that I will also be given a copy of this consent form.
9. I am aware that, if I give my consent, the interview/s will be recorded and converted to text as it has been recorded (transcribed).
10. I am aware that, if I give my consent, extracts from my interview may be reproduced in these outputs, either in anonymous form, or using a pseudonym [a made-up name or code – e.g. respondent A].
11. I am aware that my identity as EO is attributable.
12. I am also aware that my attributable position may be revealed in any publications, reports or presentations arising from this research.
13. I am aware that I may ask to be given the opportunity to review relevant extracts of the transcript of my interview, before the results of the study are published. I am also aware that I may ask for changes to be made, if I consider this to be necessary.

I have read and understood the above statements and agree to participate in this study.

Name of participant: _____

Signature: _____

Date: _____



Sue Ellen Gambin



Dr. Joseph Vancell



APPENDIX 11: Consent Form – Head of School and Year One Teachers

Participant's Consent Form

Research title: The Bee-Bot in the assessment for learning of mathematical concepts

I, the undersigned, give my consent to take part in the study conducted by Sue Ellen Gambin. This consent form specifies the terms of my participation in this research study.

1. I have been given written and verbal information about the purpose of the study; I have had the opportunity to ask questions and any questions that I had were answered fully and to my satisfaction.
2. I also understand that I am free to accept to participate, or to refuse or stop participation at any time without giving any reason and without any penalty. Should I choose to participate, I may choose to decline to answer any questions asked. In the event that I choose to withdraw from the study, any data collected from me will be stored anonymously.
3. I understand that I have been invited to participate in interviews about the participants' perceptions of how assessment of learning of mathematical concepts is achieved using the Bee-Bot, while determining effective approaches in its' use through the knowledge, beliefs, and experiences of the participants. I am aware that the interviews will take approximately one scholastic term where I will be interviewed once or twice, according to the requirements of the research. I understand that the interview/s will to be conducted in a place and at a time that is convenient for me.
4. I understand that my participation does not entail any known or anticipated risks.
5. I understand that there are direct benefits to me that include increased knowledge and better understanding of how the Bee-Bot can be used to assess learning of mathematical concepts and increased awareness about the effectiveness of Bee-Bot-enhanced mathematical learning. I also understand that this research may benefit others by gathering knowledge of how the Bee-Bot is used to assess learning of mathematical concepts and its efficacy.
6. I understand that, under the General Data Protection Regulation (GDPR) and national legislation, I have the right to access, rectify, and where applicable, ask for the data concerning me to be erased.
7. I understand that all data collected will be stored in an anonymised form on completion of the study and following publication of results.

8. I have been provided with a copy of the information letter and understand that I will also be given a copy of this consent form.
9. I am aware that, if I give my consent, the interview/s will be recorded and converted to text as it has been recorded (transcribed).
10. I am aware that, if I give my consent, extracts from my interview may be reproduced in these outputs, either in anonymous form, or using a pseudonym [a made-up name or code – e.g. respondent A].
11. I am aware that my data will be pseudonymised; i.e., my identity will not be noted on transcripts or notes from my interview, but instead, a code will be assigned. The codes that link my data to my identity will be stored securely and separately from the data, in an encrypted file on the researcher’s password-protected computer, and only the researcher will have access to this information. Any hard-copy materials will be placed in a locked cupboard. Any material that identifies me as a participant in this study will be stored securely for the duration of the study.
12. I am aware that my identity and personal information will not be revealed in any publications, reports or presentations arising from this research.
13. I am aware that I may ask to be given the opportunity to review relevant extracts of the transcript of my interview, before the results of the study are published. I am also aware that I may ask for changes to be made, if I consider this to be necessary.

I have read and understood the above statements and agree to participate in this study.

Name of participant: _____

Signature: _____

Date: _____



Sue Ellen Gambin



Dr. Joseph Vancell



APPENDIX 12: Parents' Informed Consent (English Version)

Informed Consent Form

Name of the Researcher: Sue Ellen Gambin

Title of Research: The Bee-Bot in the Assessment for Learning of Mathematical Concepts

Dear parents/guardians,

My name is Sue Ellen Gambin, and I am a student at the University of Malta, presently reading for a Master of Education in e-Learning. I am conducting a study for my dissertation titled 'The Bee-Bot in the Assessment for Learning of Mathematical Concepts', supervised by Dr. Joseph Vancell of the Department of Leadership for Learning & Innovation. You are hereby invited to provide your permission for your child to participate in this research. I would be happy to provide any clarification about the research. Please note that your child's participation is on a voluntary basis.

The aim of the study is to explain and analyse educational leaders', educators', and children's perceptions of assessment for learning of mathematical concepts when utilising the Bee-Bot, while determining effective approaches in its use through the knowledge, beliefs, and experiences of the participants.

The research involves focus groups, that is, your child will participate with a group of children who will discuss simple statements/questions about their views on the implementation of Bee-Bot in mathematics assessment. Focus group interviews will take place at school during school hours, and the participants will meet once or twice, at the most, according to the requirements of the research. Your child was chosen to participate since his/her class teacher will also be participating. Indeed, the educator has helped to select four pupils in his/her class.

You can choose whether you wish your child to participate in the research. Whatever your decision, this will have no negative effect on your child's rights. Your child may also opt out of the research at any time and without any consequence. Your child will be asked for his/her assent.

The participants will benefit from increased knowledge and better understanding of how the Bee-Bot can be used to assess learning of mathematical concepts. They will also benefit from increased awareness of the effectiveness of Bee-Bot-enhanced mathematical learning. Your child's participation does not entail any known or anticipated risks.

All the collected data will be stored in anonymised form on completion of the study. The information provided by your child will be accessible only to me, as the researcher. Extra precautions will be taken to ensure safety and anonymity. Please also note that you have

the right under the General Data Protection Regulation (GDPR) and national legislation to access, rectify, and, where applicable, ask for the data concerning your child to be erased. Data collected will be available as a dissertation from the University of Malta's library.

Thank you for your time and consideration. Should you have any questions or concerns, please do not hesitate to contact me by phone on [REDACTED], or by e-mail at [REDACTED]. You can also contact my supervisor on [REDACTED], or via email at [REDACTED].

Yours Faithfully,



Sue Ellen Gambin

[REDACTED]



Dr. Joseph Vancell

[REDACTED]

Declaration of Consent

- I have been asked to give consent for my child to participate in a study titled 'The Bee-Bot in the Assessment for Learning of Mathematical Concepts'.
- I confirm that I have read and understood the above information, or it has been read to me, and that I agree for my child to participate in this study.
- I have had the opportunity to ask questions about the research, and any questions I have asked have been answered to my satisfaction.
- I understand that I am free to contact the researcher or the researcher's supervisor to seek further clarification and information.
- I understand that my child's participation in this study is voluntary, and that my child is free to withdraw from the study at any time, without giving a reason and without consequences of any kind.
- I understand that all data is anonymous, and that there will not be any connection between the personal information provided and the data.
- I understand that there are no known risks or hazards associated with participating in this study.
- I consent to my child being audio-recorded for the purpose of the research.
- I consent to my child's data being transcribed, and that the data from the transcriptions will be stored on the researcher's computer to which only the researcher has access until completion of the dissertation.
- I understand that my child's identity will remain anonymous in any form of dissemination, written or otherwise.

Name of Parents/Guardians

Signature of Parents/Guardians

Date

APPENDIX 13: Parents' Informed Consent (Maltese Version)

Informazzjoni dwar ir-Riċerka

Titlu tar-riċerka: L-Użu ta' Bee-Bot fl-Assessjar tat-Tagħlim tal-Matematika

Isem ir-riċerkatriċi: Sue Ellen Gambin

Għeżież ġenituri/kustodji,

Jien, Sue Ellen Gambin, studenta tal-Universita' ta' Malta, u bħalissa qed nistudja 'Master of Education in e-Learning', fejn qed nagħmel riċerka dwar 'L-Użu ta' Bee-Bot fl-Assessjar tat-Tagħlim tal-Matematika'. Qed niġi megħjuna minn Dr. Joseph Vancell mid-'Department of Leadership for Learning & Innovation'. Għaldaqstant, intom mistiedna sabiex tagħtu kunsens biex it-tifel/tifla tagħkom ikollu/ha sehem f'din ir-riċerka. Għandkom tkunu tafu li l-partecipazzjoni f'din ir-riċerka hija volontarja.

L-għan ta' din ir-riċerka huwa li jiġu spjegati u analizzati l-perċezzjonijiet tal-kapijiet, għalliem, u studenti dwar l-assessjar tat-tagħlim tal-matematika meta jiġi utilizzat Bee-Bot, filwaqt li jiġu determinati modi effettivi kif jista' jintuża l-Bee-Bot. Din ir-riċerka għandha bżonn l-informazzjoni dwar il-perspettivi u l-idejat tal-istudenti.

Din ir-riċerka tinvolvi 'focus groups', fejn it-tifel/tifla tagħkom i/tkun parti minn grupp ta' tfal li jiddiskutu jew iwieġbu xi mistoqsijiet li jsirulhom. Dawn il-'focus groups' ser isiru l-iskola matul il-ħin tal-iskola, u ser ikun hemm sessjoni waħda jew tnejn, skont is-sitwazzjoni. L-ilħna ser jiġu rrekordjati. It-tifel/tifla tagħkom ġie/t magħżul/a biex j/tipparteċipa peress li r-riċerka ser issir mal-għalliem/a tiegħu/tagħha, u l-għalliem/a għen/et fl-għażla tal-istudenti.

Intom tistgħu tagħżlu jekk it-tifel/tifla j/tieħux sehem f'din ir-riċerka, mingħajr ebda effett fuq id-drittijiet tat-tifel/tifla tagħkom. It-tifel/tifla tagħkom j/tista' j/tieqaf milli j/tipparteċipa fi kwalunkwe ħin mingħajr ebda konsegwenza. It-tifel/tifla tagħkom ser ikollu/ha kollox spjegat, u ser j/tiġi mitlub/a j/tagħżel jekk j/tixtieqx j/tipparteċipa jew le.

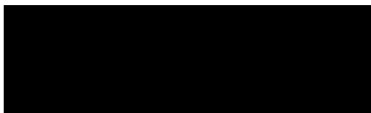
L-informazzjoni kollha miġbura ser tkun storjata b'mod anonimu meta jitlesta dan l-istudju. Jien biss, bħala r-riċerkatriċi, ser ikollu aċċess għall-informazzjoni provduta mit-tifel/tifla tagħkom. Aktar prekawzjonijiet ser jittieħdu biex tiġi żgurata l-anonimita' tat-tifel/tifla tagħkom. Għandkom tkunu tafu li għandkom id-dritt taħt ir-Regolament Ġenerali dwar il-Protezzjoni tad-Data (GDPR) u l-leġislazzjoni nazzjonali li taċċessaw, tirrangaw, u titolbu li tiġi mħassra xi nformazzjoni li tikkonċerna t-tifel/tifla tagħkon. L-informazzjoni kollha ser tkun disponibbli bħala tezi mill-librerija tal-Universita' ta' Malta.

Grazzi tal-ħin tagħkom. Tistgħu tikkuntattjawni permezz tan-numru [REDACTED], jew permezz tal-imejl [REDACTED]. Tistgħu ukoll tikkuntattjaw lis-‘supervisor’ tiegħi fuq in-numru [REDACTED], jew permezz tal-imejl [REDACTED].

Tislijiet,



Sue Ellen Gambin



Dr. Joseph Vancell



Dikjarazzjoni ta' kunsens

- Jien ġejt mitlub/a biex nagħti l-kunsens tiegħi biex it-tifel/tifla tiegħi j/tipparteċipa fir-riċerka bit-titlu 'L-Użu ta' Bee-Bot fl-Assessjar tat-Tagħlim tal-Matematika'.
- Jien nikkonferma li qrajt u fhimt l-informazzjoni t'hawn fuq, jew giet moqrija lili, u naqbel li t-tifel/tifla tiegħi tipparteċipa f'dan l-istudju.
- Jien kelli l-opportunita' li nistaqsi xi mistoqsijiet dwar ir-riċerka, u l-mistoqsijiet li staqsejt ġew imwiegħba għas-sodisfazzjon tiegħi.
- Jien nifhem li nista' nikkuntattja lir-riċerkatriċi jew lis-'supervisor' tagħha biex ikolli kjarifika aħjar jew aktar informazzjoni.
- Jien nifhem li l-parteċipazzjoni tat-tifel/tifla tiegħi hija b'mod volontarju, u li t-tifel/tifla tiegħi j/tista' j/tagħżel li j/tirtira minn dan l-istudju meta j/trid, mingħajr il-bżonn li j/tagħti raġuni u mingħajr ebda konsegwenza.
- Jien nifhem li l-informazzjoni tkun anonima, u fl-ebda mument ma jkun hemm irbit bejn informazzjoni personali u r-riċerka.
- Jien nifhem li m'hemm l-ebda riskju fil-parteċipazzjoni ta' dan l-istudju.
- Jien nagħti l-kunsens li t-tifel/tifla tiegħi jiġi rrekordjat leħnu/lehinha għall-għan tar-riċerka.
- Jien nagħti l-kunsens li l-informazzjoni li j/tgħaddi t-tifel/tifla tiegħi tiġi traskritta, u din l-informazzjoni mit-traskrizzjoni tiġi storjata fuq il-kompjuter tar-riċerkatriċi, fejn l-uniku aċċess huwa tar-riċerkatriċi biss sakemm jitlesta l-istudju.
- Jien nifhem li l-identita' tat-tifel/tifla tiegħi tibqa' anonima f'kull forma ta' tixrid ta' informazzjoni, bil-kitba jew mod ieħor.

Isem sħiħ tal-ġenitur/kustodju

Firma tal-ġenitur/kustodju

Data

APPENDIX 14: Assent Form for Minor Participants (English Version)

Assent Form



Name of the Researcher: Sue Ellen Gambin

Title of Research: The Bee-Bot in the Assessment for Learning of Mathematical Concepts

Dear participant,

My name is Sue Ellen Gambin, and I am a student at the University of Malta. I am doing a study, and I would like you to participate with a group of children, while I ask some questions. In the group, you will talk about what you think about the use of Bee-Bot during mathematics lessons. We will meet as a group at school. I have spoken to your parents/guardians about your participation, and their consent is necessary for you to participate in the research. I will take the time to explain to you any words you do not understand.

I would like to know what the teachers and students think about the use of Bee-Bot during mathematics activities, and how Bee-Bot can help. I need to ask some questions to some pupils, and I chose you as one of the pupils to share some ideas with me. You can say anything you want about mathematics activities and the use of Bee-Bot. You can choose to participate or not. Your parents/guardians have been asked for their consent for you to participate in this research. If your parents/guardians give consent, you can still choose not to participate. You can stop participating in the research whenever you want to, and nothing will happen. I will be voice-recording the discussion so that I can listen to it again afterwards and understand the discussion better.

From this research, the teachers will learn more about how to use Bee-Bot effectively during mathematics activities with their pupils. You will remain anonymous. Your name will not show in the research. Others will not know what information you shared with me.

Thank you for your time. Should you have any questions, please contact me on my mobile number [REDACTED], or by email at [REDACTED]. You can also contact my supervisor on [REDACTED], or via email at [REDACTED].

Yours Faithfully,

Sue Ellen Gambin

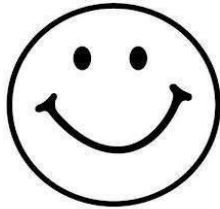
Email: [REDACTED]
[REDACTED]

Dr. Joseph Vancell

[REDACTED]
[REDACTED]

Ms. Sue Ellen Gambin has explained what she is studying.

Colour the happy face if you feel good about helping Ms. Sue Ellen Gambin.



Colour the sad face if you do not feel good about helping Ms. Sue Ellen Gambin.

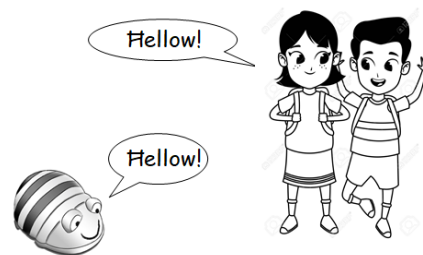


Name of Child

Date

APPENDIX 15: Assent Form for Minor Participants (Maltese Version)

Assent Form



Isem ir-riċerkatriċi: Sue Ellen Gambin

Titlu tar-riċerka: 'L-Użu ta' Bee-Bot fl-Assessjar tat-Tagħlim tal-Matematika'

Għażiż/a parteċipant/a,

Jien jismni Sue Ellen Gambin, u bħalissa jiena studenta tal-Universita' ta' Malta, fejn qed nagħmel riċerka bħala parti mill-istudju tiegħi. Jien nixtieq li inti tipparteċipa ma' grupp ta' tfal waqt li jien nistaqsi xi mistoqsijiet. Fil-grupp, ser titkellmu dwar x'taħsbu dwar l-użu ta' Bee-Bot waqt il-lezzjonijiet tal-matematika. Il-grupp ta' tfal ser jiltaqgħu l-iskola. Jien tkellimt mal-ġenituri/kustodji tiegħek, u biex inti tkun tista' tipparteċipa ikollna bżonn il-permess tal-ġenituri/kustodji tiegħek. Jekk ikun hemm xi kliem li ma tifhimx, jien ser inkun lesta biex nispjegalek.

Jien nixtieq insir naf x'jaħsbu l-għalliema u t-tfal dwar l-użu ta' Bee-Bot waqt l-attivitajiet tal-matematika, u kif Bee-Bot jista' jgħin fit-tagħlim. Jien għandi bżonn nistaqsi xi mistoqsijiet lill-istudenti, u għażilt lilek u xi tfal oħra biex taqsmu miegħi xi idejat. Tista' tgħidli dak kollu li tixtieq dwar il-lezzjoni tal-matematika u l-użu ta' Bee-Bot. Inti tista' tagħzel jekk tixtieqx tipparteċipa jew le. Il-ġenituri/kustodji tiegħek ġew mitluba biex jagħtu l-permess tagħhom biex inti tkun tista' tipparteċipa. Jekk il-ġenituri/kustodji tiegħek jagħzlu li inti tipparteċipa, inti xorta tista' tagħzel li ma tipparteċipax. Tista' ma tkomplix tipparteċipa meta trid, u ma jgħri xejn. Waqt l-attivitajiet, jien ser nirrekordja l-lehen biex jgħini nifhem aħjar.

Din ir-riċerka ser tgħin biex l-għalliema jtgħallmu aktar dwar kif jistgħu jużaw Bee-Bot fl-attivitajiet tal-matematika biex ikollhom aktar informazzjoni dwar it-tagħlim tal-istudenti tagħhom. Jien mhux ser nikteb ismek; allura, dak li tgħidli hadd mhu ser ikun jaf li għidtu li inti.

Grazzi tal-ħin tiegħek. Jekk ikollok xi mistoqsijiet, tista' tikkuntattjani permezz tal-ġenituri/kustodji tiegħek fuq in-numru [REDACTED], jew permezz tal-imejl fuq [REDACTED]. Tista' wkoll tkellem lis-'supervisor' tiegħi fuq in-numru [REDACTED], jew permezz tal-imejl [REDACTED].

Tislijiet,



Sue Ellen Gambin

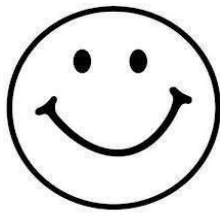


Dr. Joseph Vancell



- Ms. Sue Ellen Gambin spjegat dwar dak li qed tistudja.

Pingi bil-kulur dan il-wiċċ jekk tixtieq li tgħin u tipparteċipa fil-grupp ma' tfal oħra u ma' Ms. Sue Ellen Gambin.



Pingi bil-kulur dan il-wiċċ jekk ma tixtieqx li tipparteċipa ma' Ms. Sue Ellen Gambin.



Isem it-tifel/tifla

Data

APPENDIX 16: Interview Topic Guide – Education Officer

Name of the Research Project: The Bee-Bot in the Assessment for Learning of Mathematical Concepts

Name of Researcher: Sue Ellen Gambin

Participants: Education Officer

Interview Topic Guide:

Pedagogy

1. Do you think the Bee-Bot, as a robotic device, is effective in the teaching and learning of mathematical concepts in the Early Years? Why?

Taħseb li l-Bee-Bot, bħala mezz teknoloġiku, huwa effettiv fit-tagħlim tal-kunċetti tal-matematika fis-Snin Bikrin? Għaliex?

2. How often is the Bee-Bot used by teachers? Why?

Kemm taħseb li huwa wżat il-Bee-Bot mill-għalliema? Għaliex?

3. How do you think the Bee-Bot is effective in assessing the learning of mathematics?

Kif taħseb li l-Bee-Bot huwa effettiv fl-assessjar tat-tagħlim tal-matematika?

4. How can the Bee-Bot accommodate different learning styles?

Kif jista' l-Bee-Bot jilħaq modi ta' tagħlim differenti? (vizwali, 'hands-on', eċċ.)

5. How can teachers assess number and number processes using the Bee-Bot?

Kif jistgħu l-għalliema jassessjaw il-kunċett ta' kif l-istudenti jipproċessaw in-numri billi tuża l-Bee-Bot?

6. How can teachers assess mathematical measurements using the Bee-Bot?

Kif jistgħu l-għalliema jassessjaw il-kunċett ta' kejl permezz tal-Bee-Bot?

7. Do you think that the learning of mathematical skills using the Bee-Bot is facilitated?

Taħseb lit-tagħlim tal-ħiliet fil-matematika jista' jkun iffacilitat permezz tal-Bee-Bot?

8. Do you think the Bee-Bot affects the teaching approach towards differentiation?

Taħseb li l-Bee-Bot jaffettwa kif l-għalliema tilhaq 'differentiation' fil-mod ta' kif tgħallem?

9. Do you think that non-verbal¹⁷ pupils can demonstrate better their acquired mathematical skills when utilising the Bee-Bot?

Taħseb li studenti li huma 'non-verbal' jistgħu jipprezentaw aħjar il-ħiliet tagħhom fil-matematika meta jużaw il-Bee-Bot?

10. Do you consider visual learners at an advantage when utilising the Bee-Bot during mathematical activities?

Tikkunsidra 'visual learners' bħala avvantaġġjati meta jintuża l-Bee-Bot f'attivitajiet tal-matematika?

Assessment/gender/disadvantages

11. If yes, how does this affect their learning assessment?

Jekk iva, kif jaffettwa l-assessjar tat-tagħlim ta' dawn l-istudenti?

¹⁷ Pupils on the autism spectrum

12. Which teaching strategy do you consider most effective when implementing Bee-Bot?

Liema strategija ta' tagħlim tikkunsidra bħala l-aktar effettiva meta jiġi implimentat il-Bee-Bot? (eż., interazzjoni, struzzjonijiet diretti/indiretti, esperjenza)

13. How can formative assessment with Bee-Bot help teachers improve their teaching strategies?

Kif jista' assessjar li huwa 'formative' (formative assessment) permezz tal-Bee-Bot jgħin lill-għalliema jtejbu l-istrategiji tat-tagħlim tagħhom?

14. How can teachers address learning needs or difficulties in mathematics using the Bee-Bot for formative assessment?

Kif jistgħu l-għalliema jindirizzaw bżonnijiet jew diffikultajiet fit-tagħlim tal-matematika permezz tal-Bee-Bot għal 'formative assessment'?

15. Does gender affect assessment with Bee-Bot? If yes, why?

Taħseb li l-generu tal-istudent (jekk hux tifel jew tifla) jaffettwa l-assessjar permezz tal-Bee-Bot? Għaliex?

16. Do you think there are students who are at a disadvantage when Bee-Bot, as a technological tool, is used for mathematical assessment? Can you explain?

Taħseb li hemm studenti li jkun ta' żvantagġ għalihom meta jintuża l-Bee-Bot għal assessjar fit-tagħlim tal-matematika? Tista' tispjega ftit?

17. Do you think that the Bee-Bot can be used frequently? Why?

Taħseb li l-Bee-Bot jista' jintuża ta' spiss? Għaliex?

Training and Support

18. How do teachers learn how to use the Bee-Bot?

Kif jistgħu l-għalliema jitgħallmu kif jużaw Bee-Bot?

19. What kind of support do teachers receive to develop strategies of using the Bee-Bot for the assessment of mathematics learning?

X'tip ta' support jirċievu l-għalliema biex jiżviluppaw strategiji kif jassessjaw it-tagħlim tal-matematika permezz tal-Bee-Bot?

20. Do you think teachers need further support in implementing the Bee-Bot to assess learning of mathematical concepts? Can you explain?

Taħseb li l-għalliema għandhom bżonn aktar support ta' kif jimplimentaw il-Bee-Bot biex jassessjaw it-tagħlim tal-matematika? Tista' tispjega?

21. Do you wish to add anything else?

Tixtieq iżżid xi ħaġa oħra?

APPENDIX 17: Interview Topic Guide – Head of School

Name of the Research Project: The Bee-Bot in the Assessment for Learning of Mathematical Concepts

Name of Researcher: Sue Ellen Gambin

Participants: Head of School

Interview Topic Guide:

Pedagogy

1. Do you think the Bee-Bot, as a robotic device, is effective in the teaching and learning of mathematical concepts in the Early Years? Why?

Taħseb li l-Bee-Bot, bħala apparat robotiku, huwa effettiv għat-tagħlim tal-matematika fis-Snin Bikrin? Għaliex?

2. How often do teachers use the Bee-Bot? Why? How?

Kemm jagħmlu uzu mill-Bee-Bot l-għalliema? Għaliex? Kif?

3. Why do you think teachers find the Bee-Bot effective in assessing the learning of mathematics?

Għaliex taħseb li l-għalliema jsibu l-Bee-Bot effettiv fl-assessjar tat-tagħlim tal-matematika?

4. Do you think that the learning of mathematical skills using the Bee-Bot is facilitated?

Taħseb li t-tagħlim tal-ħiliet tal-matematika huwa ffacilitat permezz tal-Bee-Bot?

5. Do you think it affects the teachers' teaching approach towards differentiation?

Taħseb li l-Bee-Bot jaffettwa l-mod kif l-għalliema jgħallmu biex jilħqu lill-istudenti kollha?

6. How do teachers use the Bee-Bot to accommodate different learning styles?

Kif jużaw il-Bee-Bot l-għalliema biex jakkomodaw modi differenti ta' taġġim?

7. Do you think that non-verbal¹⁸ pupils can demonstrate better their acquired mathematical skills when utilising the Bee-Bot?

Taħseb li studenti 'non-verbal', permezz tal-Bee-Bot, kapaci juru aħjar il-ħiliet fil-matematika li jkun irnexxielhom jakkwistaw?

8. Do you consider visual learners at an advantage when utilising the Bee-Bot during mathematical activities?

Taħseb li jkun ta' vantaġġ għal 'visual learners' meta jintuża l-Bee-Bot waqt l-attivitajiet tal-matematika?

Assessment/gender/disadvantages

9. If yes, how does this affect their learning assessment?

Jekk iva, dan kif jaffettwa l-assessjar tat-taġġim taġġhom?

¹⁸ Pupils on the autism spectrum

10. How can formative assessment with Bee-Bot help teachers improve their teaching strategies?

Kif jista' 'formative assessment' permezz tal-Bee-Bot jgħin l-għalliema jtejbu l-istrateġiji tat-tagħlim tagħhom?

11. How can teachers address learning needs or difficulties in mathematics using the Bee-Bot for formative assessment?

Kif jistgħu l-għalliema jindirizzaw il-bżonnijiet tat-tfal fit-tagħlim tal-matematika bl-użu tal-Bee-Bot għal 'formative assessment'?

12. Does gender affect assessment with Bee-Bot? If yes, why?

Taħseb li l-generu jaffettwa l-assessjar permezz tal-Bee-Bot? Jekk iva, għaliex?

13. Do you think there are students who are at a disadvantage when Bee-Bot, as a technological tool, is used for mathematical assessment? Can you explain?

Taħseb li hemm studenti li jkun ta' żvantaġġ għalihom meta tintuża t-teknoloġija bħal Bee-Bot biex jiġi assessjat it-tagħlim tal-matematika? Tista' tispjega?

14. Do you think that the Bee-Bot can be used frequently? Why?

Taħseb li l-Bee-Bot jista' jintuża ta' spiss? Għaliex?

Training and Support

15. How do teachers learn how to use the Bee-Bot?

Kif jistgħu l-għalliema jitgħallmu jużaw il-Bee-Bot?

16. What kind of support do teachers receive to develop strategies of using the Bee-Bot for the assessment of mathematics learning?

X'tip ta' support jirċievu l-għalliema biex jiżviluppaw strategiji kif jużaw il-Bee-Bot għall-assessjar tat-tagħlim tal-matematika?

17. How can teachers be supported further in implementing the Bee-Bot to assess learning of mathematical concepts? Why?

Kif jistgħu l-għalliema jiġu mgħejjuna aħjar kif jimplimentaw l-użu tal-Bee-Bot biex jassessjaw it-tagħlim tal-matematika? Għaliex?

18. Do you wish to add anything else?

Tixtieq iżżid xi ħaġa oħra?

APPENDIX 18: Interview Topic Guide – Year One Teachers

Name of the Research Project: The Bee-Bot in the Assessment for Learning of Mathematical Concepts

Name of Researcher: Sue Ellen Gambin

Participants: Year One Teachers

Interview Topic Guide:

Pedagogy

1. How often do you use the Bee-Bot? Why? How?

Kemm tużah il-Bee-Bot? Għaliex? Kif?

2. Why do you think you find the Bee-Bot effective in assessing the learning of mathematics?

Għaliex taħseb li ssib il-Bee-Bot effettiv biex tassessja t-tagħlim fil-matematika?

3. How do you assess number and number processes using the Bee-Bot?

Kif tassessja l-mod kif l-istudenti jesploraw u jinvestigaw in-numri meta jużaw il-Bee-Bot?

4. How do you assess mathematical measurements using the Bee-Bot?

Kif tassessja kuncetti ta' kejl bħal tul u piż bl-użu tal-Bee-Bot?

5. Do you think that the learning of mathematical skills using the Bee-Bot is facilitated?

Taħseb lit-tagħlim tal-ħiliet tal-matematika huwa ffaċilitat bl-użu tal-Bee-Bot?

6. What other skills do you think children can develop through the use of the Bee-Bot for learning?

X'ħiliet oħra taħseb lit-tfal jiżviluppaw permezz tal-użu tal-Bee-Bot fit-tagħlim tagħhom?

7. Do you think it affects your teaching approach towards differentiation?

Taħseb li l-użu tal-Bee-Bot jaffettwa l-mod ta' kif tilħaq modi differenti ta' kif it-tfal jitgħallmu?

8. How do you use the Bee-Bot to accommodate different learning styles?

Kif tuża l-Bee-Bot biex tilħaq modi differenti ta' kif it-tfal jitgħallmu?

9. Do you think that non-verbal¹⁹ pupils can demonstrate better their acquired mathematical skills when utilising the Bee-Bot?

Taħseb li tfal 'non-verbal' ikunu jistgħu jesebixxu aħjar il-ħiliet tagħhom fil-matematika meta jużaw il-Bee-Bot waqt it-tagħlim?

10. Do you consider visual learners at an advantage when utilising the Bee-Bot during mathematical activities?

Taħseb li 'visual learners' għandhom vantaġġ meta jintuża l-Bee-Bot matul attivitajiet tal-matematika?

Assessment/gender/disadvantages

11. If yes, how does this affect their learning assessment?

Jekk iva, kif jaffettwa l-assessjar tat-tagħlim tagħhom?

12. Which teaching strategy do you find most effective when implementing Bee-Bot?

Liema strateġija sibt l-aktar effettiva meta tuża l-Bee-Bot waqt it-tagħlim?

¹⁹ Pupils on the autism spectrum

13. Do you think the Bee-Bot can be utilised for scaffolding mathematical learning? How?

(Scaffolding involves helping students when learning a new math concept, where the student has a lot of support at the beginning, but as the student progresses, s/he gets less support. Learning content is broken into smaller pieces.)

Taħseb li l-Bee-Bot jista' jintuża għal 'scaffolding' tat-tagħlim tal-matematika? Kif?

('Scaffolding' jinvolve l-għalliem/a li t/jgħin lill-istudent/a meta t/jkun qed t/jitgħallem kuncett gdid tal-matematika billi t/jibda b'ħafna għajnuna, imma meta l-istudent/a t/jibda t/jagħmel progress, din/dan t/jingħata inqas għajnuna. Il-kontenut tat-tagħlim ikun maqsum f'passi żgħar biex jgħin lill-istudent/a t/jifhem.)

14. How does formative assessment with Bee-Bot help you improve your teaching strategies?

Kif jista' 'formative assessment' permezz tal-Bee-Bot jgħinek ittejjeb l-istrateġiji tat-tagħlim tiegħek?

15. How do you address learning needs or difficulties in mathematics using the Bee-Bot for formative assessment?

Kif tindirizza xi bżonnijiet tat-tfal fit-tagħlim jew xi diffikultajiet li jkollhom fil-matematika waqt li tuża l-Bee-Bot għal 'formative assessment'?

16. Does gender affect assessment for learning with the Bee-Bot? If yes, why?

Taħseb li l-ġeneru jaffettwa l-assessjar għat-tagħlim meta jintuża l-Bee-Bot? Jekk iva, għaliex?

17. Do you notice any differences between boys' and girls' learning outcomes when the Bee-Bot is used for mathematics learning?

Tinnota xi differenzi bejn ir-riżultati fit-tagħlim tas-subien u tal-bniet meta jintuża l-Bee-Bot għat-tagħlim tal-matematika?

18. Do you think there are students who are at a disadvantage when Bee-Bot, as a technological tool, is used for mathematical assessment? Can you explain?

Taħseb li hemm studenti li jkun ta' żvantaġġ għalihom meta Bee-Bot, bħala għodda teknoloġika, jintuża għall-assessjar tat-tagħlim tal-matematika? Tista' tispjega?

19. Do you think that the Bee-Bot can be used frequently? Why?

Taħseb li Bee-Bot jista' jintuża spiss? Għaliex?

Training and Support

20. How did you learn how to use the Bee-Bot?

Kif tgħallimt kif tuża Bee-Bot?

21. What kind of support do you receive to develop strategies of using the Bee-Bot for the assessment of mathematics learning?

X'tip ta' support tircievi biex tiżviluppa strateġiji kif tuża Bee-Bot għall-assessjar tat-tagħlim tal-matematika?

22. How would you like to be supported in implementing the Bee-Bot to assess learning of mathematical concepts? Why?

X'tip ta' support tixtieq li jkollok biex timplimenta Bee-Bot biex tassessja t-tagħlim tal-matematika? Għaliex?

23. Why do you feel you need support to implement the Bee-Bot for the assessment for learning?

Għaliex tħoss li għandek bżonn is-sapport biex timplimenta Bee-Bot għall-assessjar fit-tagħlim?

24. Do you wish to add anything else?

Tixtieq iżżid xi ħaġa oħra?

APPENDIX 19: Focus Group Topic Guide – Minor Participants

Name of the Research Project: The Bee-Bot in the Assessment for Learning of Mathematical Concepts

Name of Researcher: Sue Ellen Gambin

Participants: Year One Pupils

Focus Group Topic Guide:

The Bee-Bot

1. Have you ever used the Bee-Bot?

Qatt uzajt il-Bee-Bot?

2. Can you describe the Bee-Bot to me?

Tista' tgħidli x'inhu?

3. How do you use the Bee-Bot?

Kif tużah Bee-Bot?

4. When did you learn how to use the Bee-Bot?

Meta tgħallimt kif tuża Bee-Bot?

Motivation

5. Do you enjoy using Bee-Bot? Why?

Tieħu gost tuża Bee-Bot? Għaliex?

Pedagogy

6. Do you like practising mathematics with Bee-Bot?

Tieħu gost titgħallem il-matematika bil-Bee-Bot?

7. Do you prefer learning mathematics with Bee-Bot, or do you prefer to work out mathematics tasks on a worksheet? Why?

Tippreferi titgħallem il-matematika bil-Bee-Bot, jew tippreferi kieku taħdem fuq karta?

Għaliex?

8. How do you know what you need to do during the activity?

Kif tkun taf xi trid tagħmel fl-attività?

9. Was there a mathematics activity utilising Bee-Bot that you enjoyed doing and still remember?

Kien hemm xi attività' fejn uzajt Bee-Bot u li ħadt gost tipparteċipa fiha u bqajt

tiftakarha?

10. Can you describe this activity?

Tista' tgħidli dwar din l-attività?

11. How do you like to work with Bee-Bot best, individually, in pairs, or as part of a team?

Why?

Kif tħobb taħdem b'Bee-Bot l-aktar, waħdek, ma' xi ħadd ieħor, jew f'team'? Għaliex?

12. What do you do when you encounter a problem while using Bee-Bot during a mathematics activity?

X'tagħmel meta tiltaqa' ma' problema waqt li qed tuża Bee-Bot f'attività' tal-

matematika?

13. Do you think the maths lesson becomes more interesting when using Bee-Bot? Why?

Taħseb li l-lezzjoni tal-'maths' tkun aktar interessanti meta jintuża Bee-Bot? Għaliex?

14. Do you prefer the teacher telling you how to make use of Bee-Bot, or do you prefer to decide how to use Bee-Bot by yourself? Why?

Tippreferi meta l-għalliema tgħidlek kif tista' tuża Bee-Bot, jew tippreferi taħseb kif ser tużah inti? Għaliex?

15. How is the lesson different when you use Bee-Bot instead of listening to the teacher explaining?

Kif tkun differenti l-lezzjoni meta tużaw Bee-Bot minflok tisma' l-għalliema tispjega?

16. Do you want to add anything else?

Tridu żżidu xi haġa oħra?

APPENDIX 20: Illustration of Coding of One-to-One Interviews

Illustration of Coding of One-to-One Interviews

Coded Text	Open Coding	Axial Coding	Memoing
<p><i>Interviewer:</i> Why do you think you find the Bee-Bot effective in assessing the learning of Mathematics?</p> <p><i>Janice:</i> To extract certain concepts, as we are discussing, above and below, up and down, left and right, also forward and backwards, erm, I find it very useful since it is hands-on. When they begin to make use of it, erm, they have a hands-on experience, where they calculate, they do not just use the Bee-Bot without a reason behind it, but there is a purpose that, listen, if we move it over here, if we move it, for example, 2 up, it goes up 2; so, they somewhat understand even direction.</p> <p><i>Interviewer:</i> How do you assess number and number processes using the Bee-Bot?</p>	<p>The Bee-Bot aids in the teaching of concepts related to direction and position.</p> <p>Pupils have the opportunity to practise a task through 'learning by doing' (hands-on).</p> <p>Learning becomes purposeful. Pupils have a purpose for learning mathematical concepts.</p> <p>Pupils practise counting and understand numbers.</p>	<p>The Bee-Bot facilitates the teaching and learning of mathematical concepts.</p> <p>When using the Bee-Bot, there is greater opportunity for learning and teaching mathematics via hands-on activities.</p> <p>Motivation resulting from purposeful learning.</p> <p>Calculation and counting activities, applying previously learned principles.</p> <p>Problem-solving techniques and the development of computational thinking abilities.</p>	<p>How can the teacher use the Bee-Bot to challenge the pupils' learning? How is this beneficial? How does the Bee-Bot assist the teacher in conveying the mathematical concept to pupils more effectively?</p> <p>The teacher can choose to make more use of the Bee-Bot since it promotes a hands-on approach.</p> <p>How does the use of the Bee-Bot affect learners' motivation? The wonders of motivation!</p> <p>How does the Bee-Bot alter the traditional teaching and learning process?</p> <p>The Bee-Bot demands pupils to use critical thinking, problem</p>

<p><i>Janice:</i> Through observation, you observe them while they are, erm, using it. You do not leave them alone, but you observe whether they are reaching the purpose. Not, as we were discussing, simply using the Bee-Bot, and that's it, but there is a purpose that, once you are observing, you can help them, "listen, let's do it again because this is not correct". You give them feedback, ongoing feedback, erm, while they are utilising it, and not just because we are using the Bee-Bot, but there is a purpose behind it that, if it is necessary to count three, we count three. So, they are counting because, sometimes, there are children whose counting skills, sometimes, they mix up the numbers; so, you observe that they are counting properly, and they are pressing the right amount, they are counting, while playing. It is like observing them, giving them feedback, and we move on from</p>	<p>The teacher can observe a pupil while s/he engages with the Bee-Bot.</p> <p>The Bee-Bot facilitates and promotes the pupils' assessment for learning.</p> <p>When a pupil experiences a challenge, the teacher can give immediate help.</p> <p>Feedback may be ongoing and immediate, making it more meaningful.</p>	<p>Observation of the pupil working on a task with the Bee-Bot is used to evaluate the pupil's understanding of mathematical concepts.</p> <p>Immediate attention to learning difficulties and individual needs.</p> <p>Ongoing feedback is simple to implement.</p> <p>The learner has more opportunities to learn from the Bee-Bot's hands-on approach, the teacher's ongoing feedback and the pupil's reasoning with the teacher.</p>	<p>solving, and logical reasoning in order to complete activities with the device. This improves computational thinking skills! How does this relate to our daily lives?</p> <p>Continuous assessment for learning and immediate feedback are possible when utilising the Bee-Bot for mathematics learning!</p> <p>The Bee-Bot assists the teacher in meeting the needs of all pupils.</p> <p>How does the Bee-Bot support the pupils' needs? How do they benefit? How does the Bee-Bot influence the pupils' participation?</p> <p>How does the Bee-Bot facilitate the understanding of a mathematical concept? How</p>
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<p>there. If they require more guidance, then you guide them. As assessment, I mostly give feedback while they are utilising it.</p> <p><i>Interviewer:</i> How do you assess mathematical measurements using the Bee-Bot?</p> <p><i>Janice:</i> As we were discussing, perhaps, erm, feedback, and you see that, first of all, you keep in mind why you are utilising it, and then you move on, you move on according to the criteria you would like to tackle. I think feedback is what helps children most as it is like you are reasoning with them, like saying we are using this, we are using this to find out about this, let's try to do it in order to get the correct answer.</p>	<p>The teacher believes that the Bee-Bot facilitates the teacher's assessment for mathematics learning and broadens pupils' learning chances.</p> <p>The teacher believes that the Bee-Bot allows for ongoing feedback and generates opportunities for learners to reason and think critically in order to attain the desired goal.</p> <p>The Bee-Bot facilitates reasoning and discussion, which help in the development of computational thinking abilities.</p>	<p>Room for the development of logical reasoning.</p> <p>The cultivation of analytical and critical thinking skills in pupils as they search for the most effective solutions.</p> <p>Make use of problem-solving techniques.</p> <p>The Bee-Bot creates an environment for learning mathematics that is engaging and interactive.</p>	<p>does it generate space for creative activities?</p> <p>How can critical thinking help a learner programme a Bee-Bot?</p> <p>What is the relationship between critical thinking and problem-solving skills? How does the Bee-Bot assist a pupil in solving a mathematical problem to obtain the desired outcome?</p> <p>What are the advantages of a learning environment that is interactive? What effect does it have on social skills and teamwork? Pupils are given the opportunity to work in teams.</p>
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APPENDIX 21: Illustration of Coding of Focus Group Interviews

Illustration of Coding of Focus Group Interviews

Coded Text	Open Coding	Axial Coding	Memoing
<p><i>Interviewer:</i> Why? Can you tell me why?</p> <p><i>Bert:</i> (shakes his head from side to side, implying the negative)</p> <p><i>Interviewer:</i> You do not know. And what do you think?</p> <p><i>John:</i> When you press the button that is (pause) left, you press the green button, in the middle, and it starts to move.</p> <p><i>Interviewer:</i> Go is the green button, right?</p> <p><i>Interviewer:</i> Do you prefer learning Mathematics with Bee-Bot, or do you prefer to work out mathematics tasks on a worksheet? Why?</p> <p><i>Dora:</i> With the Bee-Bot. Because I like the Bee-Bot.</p> <p><i>Interviewer:</i> Why do you like it?</p>	<p>The pupil was uncertain at first but was later able to explain how he uses the Bee-Bot to learn mathematics.</p> <p>The pupil was able to explain the Bee-Bot's movement using mathematical terms pertaining to position and direction.</p> <p>The pupil could describe the programming of the Bee-Bot as well as its intended path and location.</p> <p>The pupil mentioned that using the Bee-Bot to acquire mathematical concepts is her preferred method. She explained that she would utilise the Bee-Bot's buttons.</p>	<p>Use the Bee-Bot as a tool for mathematics practice.</p> <p>Enhancement of logical reasoning abilities and problem-solving skills to identify and explain the programming of the Bee-Bot.</p> <p>Understanding the programming techniques and enhancement of computational thinking skills.</p> <p>Motivation leads to enjoyment and engagement in mathematical tasks.</p>	<p>How does the Bee-Bot help a pupil's understanding of mathematical concepts?</p> <p>Frequent use of reasoning and problem-solving abilities. Enhancement of these skills. Why should these abilities be improved? How can programming assist in the acquisition of mathematical concepts? How is mathematics incorporated into programming?</p> <p>What is the relationship between programming and the development of computational thinking abilities? How will the pupil apply problem-solving concepts and methods?</p>

<p><i>Dora:</i> Because you can press the buttons.</p> <p><i>Interviewer:</i> And how do you feel?</p> <p><i>Dora:</i> Better.</p> <p><i>Interviewer:</i> You feel better. (pause) The others, what do you think? What do you prefer, learning Maths utilising the Bee-Bot, or do you prefer on a paper, writing on a paper? Which is better?</p> <p><i>John:</i> Writing them on a paper.</p> <p><i>Interviewer:</i> Is it better than using the Bee-Bot?</p> <p><i>John:</i> Writing on a paper, and then, and then...</p> <p><i>Interviewer:</i> I did not understand. Then? (pause) What did you tell me?</p> <p><i>John:</i> I said...</p> <p><i>Interviewer:</i> Can you raise your voice a little bit?</p>	<p>The pupil may have intended to say that she is motivated while using the Bee-Bot. She claimed that the Bee-Bot makes her happy.</p> <p>A pupil indicated that he would rather work on paper than with the Bee-Bot. Why? Could it be uneasiness towards using the Bee-Bot?</p> <p>Later, the same pupil described an activity he engaged in using the Bee-Bot. He referred to the Bee-Bot activity as a form of play.</p> <p>Perhaps, the pupil views the Bee-Bot as a toy and thinks that using it is equivalent to playing as he connects learning with writing on paper.</p>	<p>Hands-on experiences with the Bee-Bot increased motivation. Eagerness to learn. Focus on the learning of mathematics.</p> <p>Changes and uncertainties brought about by the shift in teaching and learning from the traditional approach to hands-on learning by doing.</p> <p>Interactive learning as a form of play. Learning through play promotes a better understanding of mathematical concepts.</p>	<p>Motivation via hands-on opportunities. Does the fact that motivation leads to engagement improve the learning of mathematical concepts?</p> <p>Learning by doing as opposed to traditional teaching and learning. What are the benefits? Will the pupil retain information more? Does it entail the pupil working harder to remember information?</p> <p>Is the Bee-Bot regarded as a tool for learning through play? How can learning through play motivate pupils to accomplish mathematical tasks?</p> <p>Does the shift in the approach to teaching and learning create</p>
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<p><i>John:</i> You place the letters, and then, and then, you talk about it, and then, you play with it.</p> <p><i>Interviewer:</i> Ok. What do you prefer, how would you like to learn Maths? How would you like to learn numbers, measurement, maybe shapes, learn shapes as well? With the Bee-Bot or on a handout?</p> <p><i>Dora:</i> With the Bee-Bot.</p> <p><i>Interviewer:</i> Why do you prefer with the Bee-Bot?</p> <p><i>Dora:</i> Because I like the Bee-Bot.</p>	<p>Another pupil prefers using the Bee-Bot to learn mathematics, adding that, using the Bee-Bot is enjoyable.</p>	<p>Adapting to technology-enhanced mathematics learning.</p> <p>The pupils practise using a digital device for learning. Student-led learning - learning that is driven by the pupils themselves.</p>	<p>uncertainties for the pupil? Is the pupil prepared for technology-enhanced learning? How does technology-enhanced learning benefit digital natives?</p> <p>Does the Bee-Bot encourage independent learning, critical thinking, and problem-solving?</p>
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