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Teachers' Views on the Use of Digital Tools to Foster Students' Curiosity in STEM Subjects

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Thesis:	30 higher education credits
Program and/or course:	International Master's Programme in IT & Learning
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Supervisor:	Wolmet Barendregt
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Abstract

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Keywords:	STEM, scientific curiosity, digital tools

Purpose: The aim of this study is to investigate teachers’ views on the use of digital tools to foster students’ curiosity in STEM subjects.

Theory: Theoretical framework chosen to lead this research and its methods is social constructionism, whose theoretical perspective provides strong conceptual support to the focus group method of data collection.

Method: Teachers’ opinions were collected through three focus groups, each consisting of five people. The collected data (transcribed focus groups sessions) was analysed using inductive, latent, constructionist thematic analysis.

Results: The results of this study indicate that STEM subjects teachers understand scientific curiosity as a positive trait that leads to asking questions, obtaining knowledge and is coming from within you. They are also in favour of using digital tools, although moderately, in class if they function properly and easy to master as they help visualize learning material. They also hope that the future toolkit will fit the pedagogical structure of the school, will be interesting for their students, will not be completely detached from the reality and will fit pedagogical views of the teachers such as using group work and different learning styles.

Foreword

This thesis would not have been possible without support of many great people. First, I would like to thank my supervisor Wolmet Barendregt for her guidance and advice in carrying out this research. Also, thank you to Stefano Gualeni, the CURIO project coordinator and all the CURIO team that gave me an opportunity to be a part of the project and provided me with constant support in this research. Thank you to Liesl Aparicio for your thorough and elaborate peer review and to Thomas Hillman for moderating this review so well. The last but not least, thank you to my family and friends for your support, your ideas and your several proofreads of this work. I hope that this study will contribute to the community and be useful to other educational researchers.

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1. Theoretical Background

1.1. Introduction

Before the end of the 20th century, information was a valuable resource. It was hard and time-consuming to obtain (going to a library, taking courses, etc.) and not easy to keep (trained memory, good home library, a lot of personal notes). With the introduction of personal computers and the Internet, however, the situation changed radically. Already from the 1990s, we frequently encounter new terms such as Internet-induced Information Overload that refer to the overabundance of information available through the Internet (White & Dorman, 2000). Just remembering or knowing something has become not as important nowadays as the ability to research, understand, explore, ask, work in groups, etc. (Gorozidis & Papaioannou, 2014). This, of course, has also led to a change in our perception of what education should be. The model where the task of the teacher is to transfer knowledge to students is becoming substituted by more creative student-centered approaches (Gorozidis & Papaioannou, 2014). New teaching methods are necessary to prepare students for the modern age (Washbon, 2012; Du Toit, Havenga, & Van der Walt, 2016).

By the end of the 21st century the need for new teaching methods was especially acute in the areas connected to science, technology, engineering, and mathematics. High dropout rates and a lack of specialists in these areas called for multidisciplinary and innovative research in the 1990s (Mohr-Schroeder, Cavalcanti & Blyman, 2015). A new interdisciplinary approach to learning became known as STEM (Science, Technology, Engineering, and Mathematics). The acronym combines four disciplines as it was (and still mostly is) applied to the teaching and learning of all or some of them. However, it is important to note that deep understanding of STEM includes not only studying four disciplines together but also "the replacement of traditional lecture-based teaching strategies with more inquiry and project-based approaches" (Breiner, Harkness, Johnson & Koehler, 2012). Despite government efforts of the last 30 years, STEM disciplines and degree programmes still have high dropout rates (Aruguete & Hardy, 2014; Johnson & O'Keeffe, 2016) while the need for specialists in STEM areas is only growing (Olson & Riordan, 2012). That is why a lot of research (including the project to which this study is related) is striving to find a way to get students back in STEM education and, consequently, STEM-related jobs.

One of the concepts that is frequently discussed as a positive influence on education, including STEM education, is curiosity. The term is vaguely defined and under-studied but seems promising according to the literature. There are several articles describing curiosity in the STEM context. Wolter, Lundeberg, & Bergland (2013) state that personal curiosity in science "can be a driving motivational factor in science classrooms" and even students that are not initially interested in a topic can become so if teachers stimulate their curiosity with instructional methods. Maltese & Tai (2010) interviewed 116 people working in STEM subjects and found that most males, for example, admitted that what led them to science in childhood was actually curiosity. Jenkins (2016) mentioned the Planet Science study where almost a half of the 1432 interviewed students complained that their science lessons did not make them '*curious* about the world and *interested* in finding out more'. These works suggest that curiosity in science (further referred to as "scientific curiosity" or, more broadly "curiosity in STEM" in this thesis) might result in more STEM graduates and even STEM employees. However, the question is, how to foster students' scientific curiosity?

According to contemporary research, one of the ways of raising students' curiosity in science is to offer them modern tools, digital and web-based. For example, Miller, Chang, Wang, Beier, & Klisch (2011) tested a web-based forensic science game on 700 secondary school students and found a significant gain in content knowledge and positive correlation between role-play experience and science career motivation. Apple, Smith, Moon, & Revelle (2016) tried to engage female middle-school students in STEM thinking by bringing STEM to apparel design and using e-textile activities. As a result, interviewed students indicated a more positive view of STEM interest after the projects were completed. The study of Nikou & Economides (2016) focused on the implementation of a self-assessment procedure in a Physics class. 66 students over seven weeks tried three modes of assessment: based on paper and pencil, computer-web and mobile devices. The last two were perceived more positively by students, showed a significant increase in learning achievement and increased students' learning motivation. All in all, digital tools seem to have the potential for raising students' curiosity in learning, and specifically, in STEM areas. What, then, prevents digital tools from being used massively in educational context?

The reason might lie in the fact that since 1980s technology integration has been made frenetically and quite inefficiently (Graesser, 2013) which, in its turn, is partly a result of insufficient teacher training (Dillenbourg, 2013). However, before blaming teachers for incompetence, Dillenburg (2013) suggests we should consider how many constraints they have and think about how to accommodate for "classroom orchestration". Classroom orchestration is the term Dillenburg uses to refer to how a teacher manages, in real time, multi-layered activities in a multi-constraints context. He sees teachers' involvement and taking their interests into account as one of the key factors that can lead to successful class management. There are indeed several examples of interesting digital projects for schools that were not integrated for the reason of bad communication with teachers. For instance, an award winning physics learning game for middle school classroom use named Ludwig is such an example (Wagner & Wernbacher, 2013). It was a pedagogically sound, and high production value game but it did not adhere to classroom needs and schools' technical infrastructures which prevented it from reaching wide-spread implementation (Marklund & Holloway-Attaway, 2018). Authors in one of the papers describing this project stated explicitly: "Digital games do not teach, teachers do. Our studies clearly show that teachers are of essential importance in digital game based education" (Wagner & Wernbacher, 2013). Taking into account Dillenbourg's (2013) study, I am prone to agree with Wagner and Wernbacher. School infrastructure and teachers' opinions are crucial to consider when planning the implementations of new technologies in the classroom.

Concluding, the possibilities of using digital tools in STEM classes to foster children's curiosity is the theme around which this research is constructed. I am looking at it from the point of view of STEM subjects teachers[1].

[1] In this thesis, both formal and informal educators in STEM areas will be called STEM subjects teachers, educators, or science communicators interchangeably. In other words, science education professionals.

This thesis constitutes a part of an EU funded Erasmus+ project named "CURIO - A Teaching Toolkit for Fostering Scientific Curiosity" (further - CURIO). The CURIO team is aiming at making a digital toolkit that would create curiosity for science[2] in Maltese schoolchildren aged 8-12. My research contributed to one of the first objectives of the project and resulted in a final report and design guidelines for CURIO (see Appendix 6), which, with some changes, are included in this thesis.

Aim of the Study

Having identified the problem in the Introduction, the aim of this study is to investigate teachers' views on the use of digital tools to foster students' curiosity in STEM subjects.

1.2. Related Works

A brief literature review of the works related to the aim of this thesis will be presented below. It will identify the gap in the literature and lead to research questions necessary to reach the aim.

The instrument used for the search of the relevant literature was the online library of the University of Malta that gives access to all the largest scientific databases including ERIC, ProQuest, Scopus, etc. The initial search terms were "STEM", "curiosity", and "digital tools". However, given that curiosity and digital tools are both vaguely defined concepts with several possible synonyms, the search terms had to be altered several times to return relevant results which were not too numerous. Four most relevant studies were chosen for this review. To broaden the document pool, I also manually examined the archives of Journal of STEM Education from which another four articles are considered in this chapter. Studies that were included in this literature review were ones that were conducted in the last 10 years, that included the aforementioned search terms or their synonyms, were in English, and that were situated in an educational context.

Curiosity in STEM

Research regarding specifically the use of digital tools to foster students' curiosity in STEM subjects is quite scarce. However, there are works describing ways of raising children's scientific curiosity or using digital tools to raise curiosity in other areas. A common issue associated with such works is the lack of a proper definition of the term "scientific curiosity" (or curiosity in STEM).

Wolter, Lundeberg, & Bergland (2013) aimed to explore what students in an introductory biology course think is relevant science to learn and why. Researchers asked them about their perceptions of relevance after engaging in two multimedia-learning environments projects. In the results, the authors mention both that students liked projects better than lectures and that several trends in student views on relevance were identified, the most important of which included curiosity (using one of these environments "stimulated personal curiosity"). However, in the detailed description of the results we can see that only two out of 32 students explicitly said that the media "piqued their curiosity", while researchers coded approximately 22% of the student comments as curiosity. It is interesting that authors' understanding of

[2] In this thesis, science and STEM are used interchangeably.

curiosity was apparently different from the students' one and it would be even more interesting to know how the authors coded the interviews.

Icel & Davis (2018) presented a more practical approach to solving the problem of STEM workforce shortage. They suggested that creating strong partnership connections between STEM-oriented high schools and local colleges would lead to lower dropout rates from the former and higher enrollment in the latter. Their findings were positive and suggested that indeed STEM focused high school curricula and preparing students for college readiness subjects can increase student graduation rates and produce STEM workforce. However, "STEM curiosity" mentioned in the name of the article and in their second research question was not further investigated or explained. The authors stated that ''exposing STEM subjects and building STEM curiosity during the high school year will be an essential pipeline for STEM workforce" but did not give a definition of what STEM curiosity was or how we could understand that it (and not something else) would lead students to colleges.

McIntyre's (2011) study is one of many examples where the terms "curiosity" and "interest" go hand in hand and are used as synonyms. McIntyre investigated the effectiveness of three case studies and associated teamwork to stimulate interest of college freshmen in engineering. Even though the name mentions interest as the subject of the study, collocation "curiosity and interest" was used three times in the text and apparently treated as synonyms or inseparable concepts. Eventually, the effectiveness was found to be dependent on several variables. However, it was rated in a rather subjective way – by the level of class interest which, in its turn, was subjectively evaluated on the quality of results produced by the class compared to results expected by the author. All in all, neither interest nor curiosity were defined or measured in the study.

The examples above do not mean that there is no research on raising curiosity in education where curiosity is properly defined. For instance, Chang, Tseng, Liang, & Yan (2013) studying the influence of perceived curiosity made an attempt at explaining the term through the presentation of situations when a person becomes curious. However, most of applied research does not specify how (scientific) curiosity is understood in their work, which makes it quite challenging to evaluate its results.

Due to the gap found in literature, it seems reasonable to make the definition of scientific curiosity one of the research questions of this thesis.

The Role of Teachers in the Introduction of Classroom Innovations

This thesis is a part of the project aiming to create a digital toolkit for schools, with teachers being its end-users. That is why the question of the extent and ways of teachers' involvement in the process of this toolkit development seems relevant to consider.

This chapter will take a general glance at the problem and will consider the role of teachers in the introduction of any classroom innovations independent from the area of studies or ways of implementation. From this general view I will be able to see which areas of this issue are understudied and to apply them specifically to the aim of this thesis.

McColgan, Colesante, & Andrade (2018) launched a course for pre-service teachers in using Minecraft for use in schools. Even though at the beginning of the course, almost all of them were strongly skeptical of using the new technology for teaching, they changed their opinion radically by the end and were advocating for the use of Minecraft in middle and high school classrooms. This study showed that short-term intervention can influence the way future teachers perceive new technology and give them confidence necessary to design their new lesson plans. The paper also describes barriers the pre-service teachers mentioned as those preventing them from trying it in the first place: the steep learning curve, time, complexity for teachers to learn the game and develop lessons, student distractibility, and the possible complexity for students to learn the game.

Johnson, Reinhorn, Charner-Laird, Kraft, Ng, & Papay (2014) interviewed 95 teachers in six high-poverty urban schools about challenges in their work and about their role in classroom improvement. Authors of the article came to the conclusion that all the improvement plans coming from the principal that are not coordinated by teachers are "incomplete and will be rejected outright or adopted perfunctorily". The authors also invoke researchers and policy makers to focus on educational reforms while they are being developed and implemented rather than assessing them *post factum*.

Gorozidis & Papaioannou (2014) surveyed over 200 teachers about the reasons leading them to participate in professional training programs and to implement innovations in class. The authors argue that professional development is essential to ensure good quality of education for students, and say it is important to know what influences teachers' decision on taking part in training. Gorozidis & Papaioannou's findings indicate that teachers' motivation should be fundamental for the success of these programs. They say that teachers play a key role in the implementation of new technologies by "organizing, grouping, motivating and guiding students" and that is why "teachers must have the right of choice to shape their training according to their needs, without restricting their personal time, while at the same time being able to be involved in the formulation of current reforms".

Armour & Yelling (2004) interviewed 85 PE teachers in England about the career-long continuing professional development (CPD) they had undertaken and recommendations they would make concerning the nature or quality of CPD provision. Authors of the research concluded that if the government wants to raise educational standards, they must "listen to the views of experienced PE teachers, and to attempt to gain a clear understanding of the lived reality of their day-to-day practice and the opportunities it offers for sustained and progressive professional learning".

From the literature we can see that teachers are not sufficiently involved in the decisions on the classroom innovations, which results in practical problems with their implementation. The studies described in this chapter make two important points:

1) First, before implementing any new educational tool in classes it is essential for policy makers to ask teachers if it meets their needs and, on which conditions they would use this tool in class.
2) Second, it is important for designers to find out teachers' opinion on what exactly they want to see in this tool to be able to use it effectively and confidently.

Based on this information, it seems reasonable to consider teachers' needs and requirements towards classroom innovations in the research questions of this thesis.

Research Questions

The literature review presented in the previous chapter identified the gaps related to the aim of our thesis (to investigate teachers' views on the use of digital tools to foster students' curiosity in STEM subjects) and led to the three research questions that this thesis will attempt to answer:

- What do STEM subjects teachers understand by "scientific curiosity"?
- According to STEM subjects teachers, what are the advantages and disadvantages of using digital tools in STEM classes?
- Which features would STEM subjects teachers like to see in the future CURIO toolkit?

1.3. Significance of the Study

This study constitutes a part of an EU funded Erasmus+ project named CURIO. It is trying to create a digital toolkit that would foster children's scientific curiosity (or curiosity in STEM) in Malta. In the light of high demand for STEM workforce such projects are readily funded by the EU. As CURIO aims to introduce its toolkit in Maltese (and possibly other European) schools, my research is an essential part of the project. It contributes to the understanding of teachers' views on using digital tools to foster scientific curiosity in class and helps assess how the future toolkit will fit the pedagogical structure. The research that formed the basis of this thesis served as design guidelines for CURIO project.

1.4. Key Concepts

The aim of this thesis is to investigate teachers' views on the use of digital tools to foster students' curiosity in STEM subjects. The three main concepts, namely digital tools, curiosity and STEM will be focused on throughout this thesis. To avoid confusion on what exactly is understood by them, a more detailed description of the three terms is provided below.

Digital tools in education

This section is dedicated to the development of digital tools in education from 1960s to the present day. Knowing the history of digital tools in education helps understand what kind of experiences and expectations teachers might have in regards to digital tools nowadays. It also explains, again, why this study focuses on teachers' views on the use of technology (and not on students', government, etc.). In this work, I define digital tools as websites, programs and any other resources that could be accessed online or offline via computers, tablets, smartphones and other devices. It was the definition we agreed upon in the framework of the CURIO project. Sometimes, researchers refer to it as "(new) technology", "(new) media" or “devices” in the literature. As this chapter presents a brief overview of the digital tools as a trend, rather than any specific tool, all the terms are used interchangeably.

The feature that stands out from reviewing literature on new technologies in education is that every invention receives quite similar reaction. There are always “the optimists” and “the pessimists” and some “wisdom” in between (Graesser, 2013). Following Graesser’s brief overview of pre- (personal) computer technology, we can see that besides tape- and video-recorders and broadcast television, a big trend in the 1960s education was teaching machines (a mechanical device to control student progress in programmed instruction). The optimists claimed, for instance, that “teaching machines are here to stay” (Guba, 1962) and discussed practical concerns of integrating them in the educational system. The pessimists believed that new machines would ultimately lead to "technological unemployment" (Leontief, 1979). Neither turned out to be completely true. However, some of the “golden mean” views sound reasonable and relevant even nowadays. For example, Howell (1968) warned educators that the new technology “can't and shouldn't be expected to be more than a help”. Caldwell (1980) pointed out that computer based education is not a “fixed system” but “a dynamic new tool” and it should not only be used for drill and practice but also to facilitate the student’s learning experience in a meaningful way to encourage “individual thought, inquiry and learning”. More recent studies support these ideas. E.g., Lowe (2001) agrees that “computer-based learning should supplement traditional instruction, not replace it” and Dillenburg (2016) says that technology would not suppress the need for teachers. The latter also mentions that learners freely exploring the environment is one of the current trends in digital education.

From 1983 digital computers changed the way we think about their capabilities. It provoked a lot of anxiety and controversy in education and required some thorough planning and actions (Graesser, 2013). From that time, several ways of integrating technology in education have been used with differing degrees of success, e.g.: Intelligent Tutoring Systems (ITS), Multimedia and Animation, Serious Games With Interactive Microworlds, Collaborative Problem Solving With Social Media. However, apart from the scale, not much has changed in how educational digital tools are tackled: with a lot of enthusiasm at the “promoting” stage and very little attention to those practical concerns at the “integrating” stage that were already mentioned by Guba (1962). Besides financial issues, teacher training is still one of the key reasons why technologies are “under-exploited in schools” (Dillenbourg, 2013). As the same author states, teachers have so many constraints and so little support, that “instead of blaming teachers and institutions, it makes sense to ask if there is something about the technology we develop that discourages its usage”. As a solution, Dillenbourg suggests several techniques to manage the class that he calls “classroom orchestration”. There are, of course, other problems concerning the use of digital tools in education but this work concentrates on the role of the teachers as it seems one of the key issues.

So where are we now and where should we go from here? Graesser (2013) mentions Lesgold’s (1983) phases of computer revolution. According to the latter, we have passed the first phase where computers were a force in the schools and by 1983 entered phase number two, which was characterized by the challenge of deciding how to use the new level of computer power. Graesser (2013), reflecting on the second phase, says that it was a “frenetic process” and decisions on technology integration were made slowly and not always wisely. He also argues that it is important to enter the next, third phase where we could critically assess "the impact of new technologies on cognition, emotion, motivation, and social interaction".

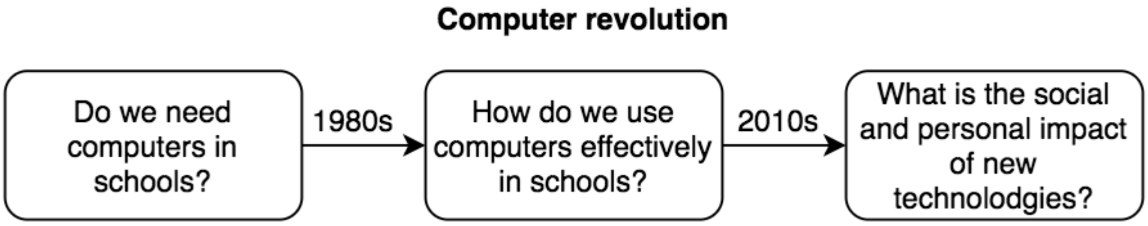


Figure 1. Phases of Computer Evolution according to Lesgold (1983) and Graesser (2013).

Another interesting question is, independent from Graesser's (2013) recommendations, what is the forecast for the technology in the nearest future? According to Collins & Halveson (2009) and their book Rethinking Education in the Age of Technology, the promises that new technology may hold are: customized education available anywhere/anytime, potential increase in self-actualization in a learning environment, and the transference of accountability from the schools to parents and students. As we can see, some of these trends are already developing, for example, through MOOCs.

To conclude, I will summarize what of the above mentioned is relevant for this study. First of all, to investigate teachers' views on the use of digital tools to foster students' curiosity in STEM subjects, I am using the definition of "digital tools" stated at the beginning of the chapter. Although there might be a slight difference in the understanding of this term, it is probably safe to assume that residents of Malta, a country with widely available PCs and Internet connection, would understand digital tools similarly. Besides, it is to expect that given the repetitive history of new technologies in education, teachers might be skeptical towards any new digital tool and unwilling to invest their time in mastering it as few inventions actually stay around long enough. It is essential to consider "classroom orchestration" in the design of educational tools because in the end teachers are those who define most of the learning process. Concerning computer revolution phases, I am mostly considering the second phase, as one of the main purposes of my study is to understand how to integrate digital tools in STEM classes in an effective way. However, the research questions also touch upon some of the aspects of the third phase, especially the question about advantages and disadvantages of digital tools. Finally, the trends of Collins & Halveson's (2009) forecast might be useful to know to see if teachers' views support or contradict those statements.

Curiosity

Curiosity is a well-known word yet a badly-defined concept in education. This chapter presents a brief overview of the research on curiosity, how it is currently defined or at least what people usually understand by it.

According to Guthrie (2009) and Silvia (2006), curiosity was fascinating different scholars for many years, however, it has been thoroughly studied only since 1950 due to the efforts of Daniel Berlyne. As Grossnickle (2016) notes, within educational contexts, curiosity has been considered to help the learning process, enhance memory and lead to higher academic performance on tests. Yet the research on curiosity is somewhat limited, partly due to the fact that there is no agreed-upon definition.

Grossnickle (2016) examined 26 scholarly articles on curiosity and came to the following conclusion: "curiosity may be defined as the desire for knowledge or information in response to experiencing or seeking out collative variables, which is accompanied by positive emotions, increased arousal, or exploratory behavior". This definition might be confusing as it includes several components of what could be understood by curiosity. If we try to explain curiosity in simple terms, according to Guthrie (2009), most researchers would agree that curiosity can be loosely defined as a desire to know or to explore. Most researchers would also confirm that there are two types of curiosity: state and trait curiosity, also known as "situational" and "dispositional" curiosity. Guthrie (2009) says the first type is a transitory feeling of curiosity that arises in a particular situation, a temporary state evoked by an activity; while the second type is a general tendency to experience interest or curiosity. He also quotes Loewenstein (1994) who notes that "effective situational interventions to stimulate state curiosity might ultimately serve to enhance trait curiosity".

There are several collocations that are frequently mentioned when discussing curiosity, namely: need for cognition, openness for experience, intellectual engagement, and wonder (Grossnickle, 2016). They are all related terms and usually constitute a part of the definition of curiosity. However, the most significant overlap can be seen between curiosity and interest. They are often used synonymously by researchers, some of whom insist that these terms should always be studied in tandem (Bowler, 2010). Grossnickle (2016) points out three main factors that distinguish curiosity from interest. Firstly, curiosity is associated with moderate levels of knowledge, while interest is present at both high and low levels. Secondly, the goal of curiosity is to reduce uncertainty and fill knowledge gaps, while interest is associated with increased attention, pursuing enjoyment and gained knowledge. Finally, enduring forms of curiosity are conceptualized as a dispositional trait that results from genetic components, while interest does not have genetic indicators.

To conclude, I will summarize what of the above mentioned relevant for this study. It is important to bear in mind that curiosity can be understood in two different ways. This research is focusing on curiosity in general. However, the CURIO project team is mainly interested in state curiosity. It is necessary to keep in mind that teachers' definitions of curiosity may differ, both from each other and from the project team's definition.

STEM

STEM is an English-language acronym, which originally comes from the US and stands for Science, Technology, Engineering and Mathematics. Currently, STEM as a term has been adopted by other countries (Breiner, Harkness, Johnson, & Koehler, 2012). Due to its origins, an overview of the literature on STEM, as presented here will have a slight focus on literature from the US. It is useful to understand what STEM is, or at least what people usually mean by it; why STEM is an important and promising area; and why the CURIO project, and thus this thesis focuses on STEM. Having said that, I would like to give a brief overview of how, what is known as STEM, was created, what it includes and which problems are usually mentioned when talking about it.

The idea of integrating several areas of science was shaped in the second half of the 20th century and originated in the US. First, as a reaction to the Space Race (Herschbach, 1997; Sanders, 2009; Breiner, Harkness, Johnson & Koehler, 2012), then it was an inevitable step that educators needed to take after seeing the rapid decline of interest in science (Potvin & Hasni, 2014). Combining several subjects and teaching them together by integrating one into another was seen as an innovative approach. For example, in the *Science for all Americans* (AAAS, 1989) the central theme is "the critical importance of addressing the inherent connections among science, mathematics, and technology" (Sanders, 2009).

The acronym STEM was introduced in 2001 by Judith Ramaley, then a director at the National Science Foundation (a United States government agency). The first acronym used for this kind of research was SMET, whose history is largely unknown but it did appear around 1993 (Mohr-Schroeder, Cavalcanti & Blyman, 2015). However, despite having a well-established acronym for over 15 years, the concept of STEM stays ambiguous. It is important to note that different parties might understand it differently.

As Breiner, Harkness, Johnson & Koehler (2012) says, depending on the specific stakeholder interested in STEM, we might encounter several ways of looking at this concept. For government, STEM might be mostly "the push for graduating more students in the science, technology, engineering, and mathematics fields" (Breiner, Harkness, Johnson, & Koehler, 2012). For some, it could include "the replacement of traditional lecture-based teaching strategies with more inquiry and project-based approaches". This definition of STEM does not even require the presence of any of the disciplines mentioned in the acronym. It is just a way of teaching any subject.

However, for other people "it only becomes STEM when integrating science, technology, engineering, and math curricula that more closely parallels the work of a real-life scientist or engineer". It requires teaching of all four disciplines with the regard of future career perspectives. These two definitions, which I could roughly call "the way of teaching" versus "the four disciplines", are the two most common approaches to considering STEM.

One way or another, STEM has made its way into the 21st century as an established phenomenon. It is not uncommon to encounter articles with such titles as "Why we still need to study the humanities in a STEM world" (Strauss, 2017). It is now not only the matter of Space Race but everyday life. Researchers, government and media insist on the opinion that we are in the middle of a STEM crisis. The US President's Council of Advisors on Science and Technology in their report (2012) claimed that there is a need for approximately 1 million more STEM professionals than the U.S. will produce. A similar concern has been raised in other countries, such as Malta, which is why projects like CURIO receive immediate government and EU support. As Tate, Jones, Thorne-Wallington & Hogrebe (2012) put it, efforts are being made "to increase the quantity of highly competent citizens who are able to understand and apply STEM concepts to every aspect of their lives—for example, health decisions, employment, voting, entrepreneurship, environmental debates, and financial stewardship". Additionally, a lot of literature points out the importance of getting more females and people of colour or low income into STEM fields (Master, Cheryan, Moscatelli, & Meltzoff, 2017; Ononye & Bong, 2017; Kant, Burckhard & Meyers, 2017; Smith, Lewis, Hawthorne & Hodges, 2012; Freeman, Alston & Winborne, 2007). Finally, the proposals on education reforms in STEM areas are constantly appearing in press and science journals (McNeil, 2006; Jacobson 2008; Morrison & Bartlett, 2009; Castleman, Long & Mabel, 2017).

On the other hand, we can also see some skepticism towards “STEMmania” and claims that “those practices usually appear suspiciously like the status quo educational practices that have monopolized the landscape for a century” (Sanders, 2009). Several researchers argue that the shortage of people in STEM field jobs is seriously exaggerated and the crisis is a myth (Charette, 2013; Xue & Larson, 2015). Some of the criticism is connected to the fact that STEM education is indeed very vaguely defined and what STEM education means is still open for interpretation and debate (Mohr-Schroeder, Cavalcanti & Blyman, 2015; Brown 2012).

To conclude, I will summarize what of the above mentioned relevant for this study. This research was based on the assumption that STEM is indeed in crisis as students show very low results in STEM subjects, especially in Malta. According to a recent PISA National Report, “performance in Science of Maltese students is lower than expected given the expenditure on education in Malta” (OECD, 2015). This research aims to investigate teachers’ views on the use of digital tools to foster students’ curiosity in STEM subjects. For that, I am mostly relying on “the four disciplines” definition of STEM, and I am mainly interested in the views of educators teaching one or more of these disciplines, rather than seeing STEM as a teaching strategy. This is in line with the definition of STEM as adopted in the CURIO project, although being sponsored by the government, some other considerations (such as the perspective of producing more science graduates) may have played a role. However, it is necessary to keep in mind that teachers’ definitions of STEM may differ from the one adopted here.

2. Research Methods and Theory

2.1. Social Constructionism and Focus groups

As this research is mostly qualitative, there are three main methods that could be employed in collecting data for it: participant observation, individual interviews, and focus groups (Morgan, 1997). Bloor, Frankland, Thomas, & Robson (2001) say that focus groups are useful when we want to study "topics relating to group norms, the group meanings that underpin those norms and the group processes whereby those meanings are constructed". As my research is attempting to generalize educational practices, that was the first argument in favour of focus groups. Additionally, "the energy and depth of human interactions established during focus group process can produce thick, meaningful cultural data" (Puig, Koro-Ljungberg, & Echevarria-Doan, 2008). It seemed useful to see "how social reality gets collectively constructed" (Puig, Koro-Ljungberg, & Echevarria-Doan, 2008), so that was the second argument for the use of focus groups. Finally, focus groups allow to observe a large amount of interaction on a topic in a limited period of time and enable interaction on a topic meaning that participants can instantly see similarities and differences in their opinions and reach conclusions (Morgan, 1997). For the time-constrained setting of this research, focus groups seemed, again, a wise choice.

Epistemologically, this research takes an interpretivist position, i.e. an interpretation of people's thoughts by means of social immersion (Wilson, 1997). In other words, it attempts to draw meaning from the personal experiences of subjects engaging in a specific form of social interaction. The theoretical framework chosen to lead this research and its methods is social constructionism (Berger & Luckmann, 1966). Epistemologically, the theory of social constructionism supports a systems perspective because "it puts forth the belief that no knowledge exists outside the systems individuals inhabit. Individual knowledge is based on co-created meanings derived from social interactions within a given context" (Puig, Koro-Ljungberg, & Echevarria-Doan, 2008). I believe that in a good research, "method is fully embedded in theory and theory is expressed in method" (Quantz, 1992), that is why it was very important for me to find a way of data collection that would be strongly supported by the theoretical perspective.

As the focus groups were conducted within the CURIO project, two other researchers took part in their organisation. Therefore, this chapter will refer to all three people planning and executing focus groups as "we".

2.2. Sampling Strategy

Selection of Educational Institutions and Participants

As we wanted to provide the maximum variety of participants, we approached the selection of the institutions for the focus groups from different perspectives. We used a 'maximum variation' sampling strategy that sought to increase differences between schools in order to distil common patterns (Patton, 1990). We applied the following criteria to choose a balanced representation of educational institutions: location (urban/rural), type (primary/secondary state school/science center), and socio-economic background (affluent/deprived).

The first establishment we contacted was the local science center where all primary science teachers of state schools of Malta hold weekly meetings. The local education system implies that at the primary level all state schools share several science teachers and they are all connected through a science center. In that way, all science teachers received an email invitation to participate and five of them volunteered to do so.

Another perspective we decided to tackle was that of science communicators working in a local interactive science center for children. The invitation was sent to all the employees that work directly with children and most of whom have a background in school teaching. Five employees from this interactive science center volunteered to take part in the focus group. All five of them conduct science workshops and make interactive tours with children of different school age. Four of them had experience in teaching science at school.

Our third and final location was the secondary state school in a remote area of the country that provided the views of teachers of low-ability students or those from underprivileged families. We contacted one of the teachers who invited all STEM teachers that were available at the school, and five of them volunteered to participate. They were Maths and IT secondary school teachers.

As a result of our selection of educational institutions in Malta, the study involved altogether 15 people (5 people in each focus group) with a STEM background: primary/secondary STEM subjects teachers, science communicators, or both. By means of a small demographic form (see Appendix 1) that was given to each participant before each focus group we are able to make the following summarizations. Among the participants, there were 10 females and 5 males from approx. 20 to 60 years old, having from 1.5 to 25 years of experience, mostly teachers of Maths, Science or IT from different state schools or non-formal education institution. Detailed demographic information can be found in the Appendix 2. Due to the variety of roles, participants could provide insights on the use of digital tools from different perspectives.

All three focus groups were conducted in Malta throughout January-February 2018. For privacy reasons, names of the organizations are not revealed in this study.

2.3. Data Gathering

Protocol for the Focus Groups

Planning. According to Morgan (1997), after resolving three main factors influencing the planning process – ethical concerns (see Chapter 2.4), budget issues, and time constraints – we moved on to the selection of educational institutions and participants, as described in detail in Chapter 2.2. According to Morgan (1997), "focus group projects most often (a) use homogeneous strangers as participants, (b) rely on a relatively structured interview with high moderator involvement, (c) have 6 to 10 participants per group, and (d) have a total of three to five groups per project". Our case relies mostly on these rules of thumb. However, as focus groups "are most useful as a point of departure in the planning process", we took the liberty of changing some details and customizing our design.

The first change was that, some of the participants were not complete strangers but colleagues working within the same institution. It was done for the reasons of practicality (it is easier to gather teachers from one school). Second, each of the groups had 5 participants which was mostly due to time concerns: large focus groups would require around 2-2.5 hours, while the participants were willing to sacrifice only up to 1.5 hours. And finally, we conducted a total of three focus groups sessions. This was due to time constraints and the fact that "three focus groups were also enough to identify all of the most prevalent themes within the data set" (Guest, Namey, & McKenna, 2017).

Protocol. Before going into details of the protocol, I will mention the role of moderators. Throughout all three focus groups there were three moderators: Margarita Iashchina (the author of this work) as a primary instructor, Sandra Dingli (an Associate Professor at the University of Malta) as an assistant instructor (she was not present during the last focus group), and Danielle Farrugia (Science Communicator at the University of Malta, former science and physics teacher at Maria Regina Mosta Secondary School in Malta) as a scribe and photographer.

The protocol for every focus group was the following:

1. warming up exercise
2. reading the Information letter and filling demographic and consent forms
3. discussion
4. closing comments, exchanging emails

1. **Warmup**. For every focus group we decided to employ a game known as "Two Truths and a Lie" as a warming up exercise. Within the game, participants had to share two real and one imaginary story about their lives and other people were supposed to guess which was a lie. It worked as an ice-breaker that enabled participants to relax, talk informally and joke.

2. **Filling the forms**. As we were gathering some personal information and all the meetings were audio- and video-recorded, participants were familiarized with the conditions of the research through the Information Letter (see Appendix 3) and all signed the Consent Form (see Appendix 4) that ensures them of anonymity and use of their personal information exclusively for the purposes of this research. We also asked the participants to fill a Demographic form (see Appendix 1) to ensure demographic variety of our sample.

3. **Discussion**. The main part of the focus group involved the moderator (author of this thesis) asking participants questions and leading their discussion. It relied on a structured "interview" and consisted of six questions (for the list of questions refer to Appendix 5):

    Questions 1 and 2 concerned the definition of scientific curiosity. At first, participants were asked to write their own definitions on a piece of paper. Then they were asked to discuss what they wrote in groups and report the results. During the first focus group, participants were also given the definition of scientific curiosity provided by one of the CURIO team designers Marcello

Gomez and asked to compare their personal definitions with it. However, with the consequent groups we did not feel the necessity to do that as it seemed to limit their discussion on personal perception of scientific curiosity which was of more importance to this research.

Question 3 concerned science topics that arouse curiosity in children and, in contrast, topics that do not arouse it. Participants were asked to discuss which topics make children curious and what these topics have in common, in their opinion.

Question 4 concerned the use of digital tools for work (with students in the STEM area). Participants were asked if they ever used any digital tools and which ones if they did.

Question 5 concerned specific features that they would like to see in the future CURIO toolkit. It was meant to be an open question that could elicit different kinds of aspects.

Question 6 concerned examples of excellence that link curiosity, STEM and digital tools. We also asked participants to contact us by email if they recall more examples.

4. **Closing comments**. All the focus groups were ended with thanking participants for volunteering to take their time to participate in the research. They were also asked, again, to send us an email if they had additional suggestions for our project.

2.4. Ethical Considerations

The study received the approval from University Research Ethics Committee (UREC) of the University of Malta before the data was collected. As it did not involve children, animals, personal questions or any other sensitive subjects, no further ethical board was needed. All participants signed the Consent Form (see Appendix 4) that ensures them of anonymity and use of their personal information exclusively for the purposes of this research.

2.5. Validity and Reliability

Validity. To reach my aim, I conducted three focus groups with science teachers and science communicators in Malta. The sampling strategy was explained in more detail in chapter 2.2. The choice of participants seems reasonable: it was quite a homogeneous group of teachers and other educators from different institutions all of which taught STEM subjects to students on a regular basis. Some of the participants in my focus groups were colleagues working within the same organisation (focus groups 2 and 3) and some came from different schools but were acquainted from before. Morgan (1997) says that although the rule of thumb favors strangers over acquaintances to participate in a focus group, the necessity of this is actually a myth. The main risk in case with acquaintances is that participants might not share some thoughts as they take them for granted (Morgan, 1997). To avoid this risk, participants were asked to express their opinions openly and were asked to clarify any inside terms they used during focus groups.

Reliability. Before writing this thesis, I worked as a part of the CURIO team. After conducting each focus group I produced a summarizing report that was checked by three colleagues; two university professors who have vast experience of conducting focus groups and the project director. The final report on the conclusions I drew from all three focus groups was read by the whole CURIO team and commented upon. Based on these comments I made changes in my report that were also taken into account when writing this thesis. The reliability of this thesis can therefore be considered sufficient.

3. Analysis

All focus groups were video- and audio-recorded and transcribed which created almost 50 pages of raw data. Thematic analysis was chosen as a method of analysing this data. Braun and Clarke (2006) recommend this type of analysis to beginner researchers as it is easy to learn and do. Among its advantages, it allows the researcher to summarize key features of a large body of data and can generate unanticipated insights. All these features of thematic analysis were useful for this thesis and that is why this method was chosen to deal with the data.

According to the definitions of Braun and Clarke (2006), this research used inductive, latent, constructionist thematic analysis. It is inductive as it is strongly connected to the data and does not try to fit any theoretical framework (themes were data-driven). It is also latent as it tends to examine underlying ideas and assumptions and go beyond description. Finally, it is constructionist as it focuses on the socio-cultural context rather than individual motivations.

Braun and Clarke (2006) suggest that the following steps should be performed to conduct a thematic analysis:

1) familiarising yourself with your data
2) generating initial codes
3) searching for themes
4) reviewing themes
5) defining and naming themes
6) producing the report

The data was collected in different educational institutions through focus groups with teachers and science communicators.

3.1. Thematic Analysis Steps

Familiarizing myself with the data

Familiarising yourself with your data is phase 1 according to Braun and Clarke's (2006) guide through thematic analysis. They state, "it is vital that you immerse yourself in the data to the extent that you are familiar with the depth and breadth of the content. Immersion usually involves „repeated reading" of the data, and reading the data in an active way – searching for meanings, patterns and so on." As my data was audio- and video- recorded, the first step was to transcribe it. Fortunately, I was also the one who collected the data, which helped me to come to the analysis "with some prior knowledge of the data" and "some initial analytic interests or thought" (Braun & Clarke, 2006). In this way, I employed three ways of familiarizing myself with my data: 1) collecting it myself in an interactive way via focus groups, 2) listening to audio- and video-recordings several times and transcribing them, 3) repeatedly reading the transcript. The way I collected the data is described in the previous chapter, so I will focus on the last two points.

- Listening to audio- and video-recordings:

Each recording was roughly 1 hour 15 minutes (as it did not include the warming-up part). I listened to the recordings 3 times:

1) during the first time I did raw transcription that included only utterances of the participants without their code names or any punctuation;

2) during the second time I edited transcripts, adding some missing parts and correcting mistakes;

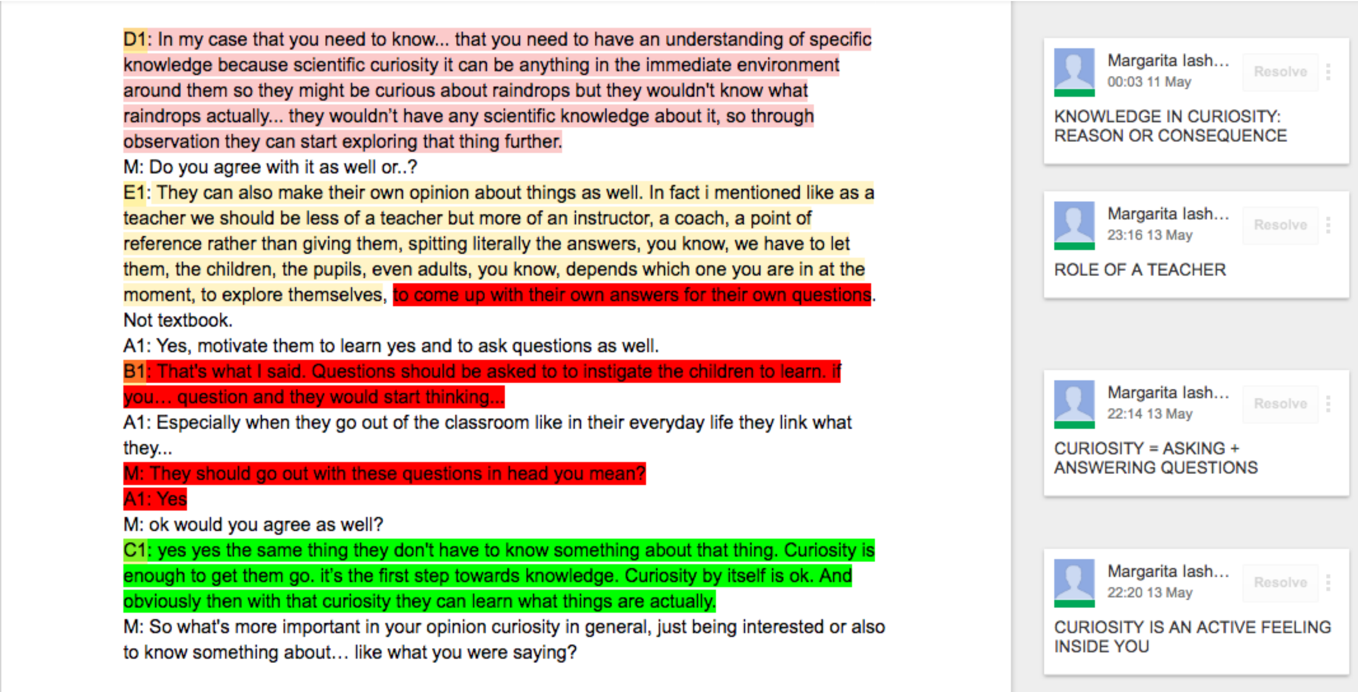
3) during the third time I watched the video recordings to add participants' code names, punctuation and remarks, e.g. "all nodded" or "all laughed".

Together with actually conducting these focus groups, listening to the recordings several times made me quite familiar with the content of all three focus group discussions. I obtained a clear understanding of the structure of all conversations and could navigate through them easily.

- Reading the transcript

Reading through the transcript was important to get a more objective picture in contrast with the one you have after listening to recordings. Absence of loud voices, intonations and interruptions helps to see which themes actually arose more often (rather than "more loudly") than others. Reading also revealed some common patterns of discussion: there usually were two active people starting a topic, two semi-active people who would give some additional comments and one who would hardly say anything. A lot of themes appeared in all three groups, some were quite unique due to personal reasons or the specialization of the place where the group was conducted. However, some of the unique themes seemed not less important than those repeated throughout all discussions.

Generating initial codes
I read through all 3 transcripts to pinpoint what "big" topics were discussed.
I tried to identify similar topics throughout 3 focus groups and gave them initial code names, e.g. "Boring because common" (speaking about science topics), or "Knowledge in curiosity: reason or consequence":



D1: In my case that you need to know... that you need to have an understanding of specific knowledge because scientific curiosity it can be anything in the immediate environment around them so they might be curious about raindrops but they wouldn't know what raindrops actually... they wouldn't have any scientific knowledge about it, so through observation they can start exploring that thing further.
M: Do you agree with it as well or..?
E1: They can also make their own opinion about things as well. In fact i mentioned like as a teacher we should be less of a teacher but more of an instructor, a coach, a point of reference rather than giving them, spitting literally the answers, you know, we have to let them, the children, the pupils, even adults, you know, depends which one you are in at the moment, to explore themselves, to come up with their own answers for their own questions. Not textbook.
A1: Yes, motivate them to learn yes and to ask questions as well.
B1: That's what I said. Questions should be asked to to instigate the children to learn. if you… question and they would start thinking...
A1: Especially when they go out of the classroom like in their everyday life they link what they...
M: They should go out with these questions in head you mean?
A1: Yes
M: ok would you agree as well?
C1: yes yes the same thing they don't have to know something about that thing. Curiosity is enough to get them go. it's the first step towards knowledge. Curiosity by itself is ok. And obviously then with that curiosity they can learn what things are actually.
M: So what's more important in your opinion curiosity in general, just being interested or also to know something about… like what you were saying?

Margarita Iash… 00:03 11 May Resolve
KNOWLEDGE IN CURIOSITY: REASON OR CONSEQUENCE

Margarita Iash… 23:16 13 May Resolve
ROLE OF A TEACHER

Margarita Iash… 22:14 13 May Resolve
CURIOSITY = ASKING + ANSWERING QUESTIONS

Margarita Iash… 22:20 13 May Resolve
CURIOSITY IS AN ACTIVE FEELING INSIDE YOU

Figure 2. An example page of initial codes

Searching for themes
When identifying themes I was relying on two factors: ideas continuously repeated throughout most or all focus groups were marked as a possible theme; and ideas that could radically change the project perception of some question were also marked as a possible theme.

Reviewing themes
When reviewing the themes, I was striving to combine several ideas in large sets to identify general trends. Several themes were changed and some parts of data were coded as different themes in the process of reviewing.

Defining and naming themes
When I reached the conclusion on what should be combined into final themes, I attempted to name them in a way that would reflect all the ideas included in it and at the same time would not be too long.

Producing the report
The report produced on the basis of the themes identified in the focus groups data constitutes the Results chapter of this thesis.

4. Results

This chapter is structured in accordance with the three research questions of this thesis and presents data that would strive to give answers to all of them.

4.1. Defining "scientific curiosity"

Defining scientific curiosity was one of the most difficult questions for teachers. While not many participants managed to produce a full definition of the concept, the focus group discussion helped reveal what components, in teachers' opinion, are essential to be curious and what curiosity might lead to.

Knowledge as a source or as a goal

The subject of "knowledge" arose in every focus group in one way or another while discussing the definition of scientific curiosity as shown in 3 excerpts from different focus groups:

> M[3]: *What do you think is wrong with this definition?*
> D1[4]: *In my case that you need to have an understanding of specific knowledge because scientific curiosity, it can be anything in the immediate environment.*
>
> C2[5]: *Curiosity would trigger you to acquire new knowledge.*
>
> D3: *I think the keypoint is that a person understands that everything has a scientific explanation.*

It was clear that knowledge, or scientific knowledge, had some connection with the concept of scientific curiosity. However, the nature of this connection turned out to be ambiguous. Participants were unable to determine if people needed knowledge to become curious (knowledge as a source) or if they needed curiosity to become knowledgeable (knowledge as a goal). Some teachers stated that if you do not have at least some knowledge of a particular thing, you will not want to explore this thing, i.e. to be curious:

> E1: *I really think that you really need some knowledge to understand that you have a specific lack of knowledge in something.*
>
> B2:*...because if I have something related to chemistry... if I don't understand what I'm reading I can't understand what I'm actually trying to...*
>
> D3: *If you don't know that there is explanation you will not seek the explanation.*

Others argued that knowing the facts is not as important. They stated that curiosity as an inner feeling will make you explore things and that will lead you to the knowledge:

---

[3] Here and further: M (Margarita) - code name of the interviewer.

[4] Here and further: A1...E1, A2...E2, A3...E3 - code names of the focus group participants. The number after each letter refers to the number of the group.

[5] Here and further: a border between two pieces of discussion is signified by a blank line between them.

D1: *It can be anything in the immediate environment around them so they might be curious about raindrops but <...> they wouldn't have any scientific knowledge about it, so through observation they can start exploring that thing further.*

C1: *Yes, yes, the same thing they don't have to know something about that thing. Curiosity is enough to get them go. It's the first step towards knowledge.*

B3: *Curiosity can lead you to this knowledge. Maybe you have a curiosity how something works, for example, and then you've tried to find the knowledge to explain it.*

C2: *Curiosity would trigger you to acquire new knowledge.*

After a lively discussion most teachers agreed that knowledge is not a primary component in curiosity but that having some knowledge can help to ask the right questions:

B1: *My opinion, I think, ok, you should know a bit of knowledge but it's not the most important…*

E1: *Curiosity should be more important.*

B2: *And knowledge isn't necessary but sometimes it helps.*

C2: But you don't necessarily need knowledge.
B2: No, not necessarily but sometimes it will make it easier.
A2: If you do have basic foundation it can make it easier for you.
B2: Even the way you're setting question, it will help. But it's not necessary.

E3: It's a mixture because curiosity is someone who asks a lot

Curiosity comes from intrinsic motivation

Defining such an abstract term as curiosity seemed like a challenging task for our participants. When the teachers were faced with this question, they sometimes tended to define curiosity through curiosity itself or through similar concepts such as "interest":

A2: *I wrote that curiosity is getting to know and being curious about how things around us work and why things happen.*

C1: *Curiosity by itself is ok. And obviously then with that curiosity they can learn what things are actually...*

D2: *Curiosity would be useless if you're just curious.*

C2: *But interest would feed curiosity because if you're not interested in something you wouldn't be curious about it.*

Those definitions were quite vague but further discussion shed some light on what teachers could mean by "curiosity is being curious". Some participants mentioned that curiosity is a wish to learn something new:

> A2: *...wanting to know how things around us work.*
>
> B2: *You need to want to learn more to be asking these question, otherwise you wouldn't be asking these questions.*
>
> E3: *We agreed on most of the things that scientific curiosity is when someone wants to know how the things work, what is happening around us...*

Most importantly, teachers said that curiosity is a feeling that is 'inside' you. In other words, only intrinsic motivation can make you curious:

> C2: *I wrote that curiosity is the urge for exploration and it encourages play and experimentation.*
>
> E2: *We basically wrote a sense of eagerness or wonder to understand and discover truth about what is around us in an objective way.*
>
> D2: *But curiosity has to come within you, it doesn't matter... it's not something you have to do, it just comes within you*

Asking and answering questions

Teachers mentioned that another important component of scientific curiosity concerned asking questions, especially such questions as "how?" and "why?":

> B1: *That's what I said. Questions should be asked to instigate the children to learn. If you ask a question and they would start thinking…*
>
> A1: *Especially when they go out of the classroom like in their everyday life they link what they...*
> M: *They should go out with these questions in head you mean?*
> A1: *Yes.*
>
> C2: *Curiosity is the reason why we further think about how things happen and why is that and how…*

However, the essential part of "scientific curiosity" is that students should ask these questions and find answers to these questions all by themselves:

> E1: *...to come up with their own answers for their own questions.*
>
> B2: *In my opinion, scientific curiosity is about asking questions, about what's around you, how things work, where things are, how things get to be, and then finding a way*

how you can actually answer these questions, be it through experimentation, through discussion...

D2: *I think that it does make sense that thinking of questions and answering because curiosity would be useless if you're just curious, if you don't try to find out the answers for it, you know. So it makes sense that questions and you try to find the answers.*

E3: *...and why and how to go about certain facts and even non facts and how to come up with solutions or invention. important is how and why questions and how to go about…*

A3: *Maybe what happens if variables changed if something changes then what happens then. Looking up reasons, ask him questions and how to find reasons.*

4.2. Advantages and disadvantages of using digital tools in STEM classes

A lot of themes arose while discussing the use of digital tools in class. The most prominent of them, that is called here "Physical world is as important as virtual", concerned the importance of keeping a balance between the reality and the virtual world. Within this theme, participants attempted to answer such global questions as: "To which extent do we need to use digital tools in class?", "Which consequences might we meet if we use them too much?", "Are we becoming lazy/addicted/obsessed both as teachers and as humans?". That is why this theme is discussed before others – before delving into pros and cons of using digital tools in STEM classes, it was decided to present participants' views on whether we need to use them at all and to which extent. After that, however, two other themes are presented that represent advantages and disadvantages of the use of digital tools in STEM classes: "Digital tools help visualize information" and "Digital tools are unreliable and hard to learn" accordingly.

Physical world is as important as virtual

As it was mentioned earlier, this theme was the most discussed within all focus groups. Participants expressed their concerns about using digital tools from different points of view but all led to the fact that we still live in the physical world and we need to interact with it. Some teachers said that there should be a balance in class between hands-on and virtual activities:

D1: BBC Syd the Science Kid there are different options. In my case, I use them either as pre hands-on activity or as post hands-on. So mostly to introduce or consolidate what... But not… I wouldn't use interactive games only. So there would be the hands-on as well.
M: Some material?
D1: Yeah. I believe children are getting engaged through the hands-on activity, not just virtual... Because the environment around us is the physical environment. We don't live in the virtual environment. So it's useless to just focus on virtual…

B2: But we don't tend to focus too much on technology. It's usually our workshops are around 45 minutes one hour long so most of the time it's about getting them here and getting them to do something with their hands <...>.
D2: We focus more on hands-on.

Specifically, participants mentioned that sometimes even educators are in 'danger' of getting too used to digital tools:

A1: Yes much easier resources, you know, and convenient than combine them in groups...
E1: It's much easier to use an online game then rather bring your own material.
M: So are you afraid of getting lazy?
E1: Exactly.

They highlighted the importance of remembering that digital tools should not substitute other tools we have been using:

E1: Like every tool, it's something that complements you. It's not the only way to teach. But it's an easier way how to deliver your message basically.

A1: Like my colleagues said, sometimes there is like a duality that these virtual things take place of the actual hands-on activities of the class maybe...

According to the educators, the reason for that lies in the fact that we still live in the physical world and need to have some physical skills:

E1: Again, not on the wrong. Because at the end of the day however realistic and however, how can I put it, true it might be, still there is a physical environment. And we need to actually show "hey, listen, this is not our world, this is our world" like we mentioned before. But again we are more moving towards the virtual reality, more and more each day, rather than what's really happening.

B2: Not to forget certain …. to put aside certain skills because you need your hands for certain things. But then in certain jobs it's about technology and thinking etc, but in other jobs you need to use your hands so you can't just not focus on those in class.

However, participants also mentioned that in the modern age children should be always offered both opportunities to develop: the virtual and the physical one:

A2: I believe you should be offered both opportunities.

B2: I would say both because for example if you see kids, they love building things and you see them building things. But if you give them Minecraft they like building on Minecraft as well.

C2: It's good to keep and maintain the balance between the two. I mean not using technology all the time because it would be a bit too much then.

Digital tools can help visualize information

After putting aside all the global questions, participants shared why they like to use digital support. The simple reason was that it is very realistic, so it helps visualize material to grab students' attention or to explain difficult abstract concepts:

> *B1: Because it's so abstract you know it's something which children cannot see. We always try to make them see it.*
> *E1: Yes yes yes, most of the apps today they are quite realistic, so why not using them?*

> *C2: ...even if we're going to do a lesson about different types of animals, vertebrates and invertebrates rather than just writing them down on the board or on the chart will let them use the computer to click on the image and drag it to which column. It's more, it's an experience for them and they focus more or sometimes they do second try.*

> *A2: Ok I do think that videos help and YouTube videos and so on for them to understand certain things. Cause if it's more visual than rather than speaking about it or let's say... I don't know... talking about the animals. If you show a picture of an animal or video of that butterfly that it has eyes then they actually see it.*

Digital tools are unreliable and hard to master

Interestingly though, despite claiming to use digital tools quite a lot in their work, participants mentioned their disadvantages more often than their advantages. The first drawback of the use of digital support was the fact that it is quite often unreliable:

> *D2: I think it's because of the problems that can arise*
> *M: For example?*
> *A2: If it's online and we don't have internet.*
> *D2: Or when it's something old school you know it is more reliable. I think that's that does affect our decision to use or incorporate technology.*

> *D3: This is my lab my internet connection is most unreliable. I'm very angry about it. PCs are extremely slow and sometimes when they eventually boot you might not get a reliable connection.*

Another quite important issue was that a lot of students and even educators are still not so confident with using IT and, therefore, would not be able to properly use some of the digital tools:

> *E3: But even they use internet for not for learning, for chatting, for Snapchat. If they want to apply for examinations they come to our room to help them. I'm a guidance teacher also. It's a very hectic week before applying for the exam, for example. They do not know how. But they still know how to buy online but not applying for the exam.*

> *B3: Or they don't know how to use it*

E3: Some of them are IT illiterate <...> Nowadays being a teacher it makes you... you know there are lecturers at the university who are illiterate according to... if you don't know how to present a proper document, for example, it makes you illiterate nowadays. You should work in it, it should be a part of education since grade one, to learn how to be appropriately IT literate.

Those educators who have no issues with using technology admitted that they might be reluctant to spend time to learn new software:

D1: I think it would be a learning curve for me <...> so to control that environment it would be in my case it would be a learning curve because I have to try it out and see what works and what doesn't. And also how to manage the tool itself.

E2: For instance, I would like to use the illustrator but I know it will take a lot of energy and a lot of time to learn it.
M: So something hard to learn?
E2: Not something hard to learn but which isn't in the core of what I really need to do at the moment. So that would mean in order to spend all the time learning it I'm spending less time on something else. Because it's not just me using the illustrator, I need to learn it. And for me it's a bit difficult
A2: Same thing with a coding one.

4.3. Features of the future toolkit

One of the most widely discussed questions in every focus group was that of the features educators would like to to see in a future toolkit. Participants shared a lot of ideas on how to make a successful product. These ideas were grouped into 4 major themes that you can see below in the four following subchapters. According to the educators, the thing mentioned below are essential for the product to be successfully introduced in Maltese schools:

E2: *First thing that comes to mind, it might be unfortunately, it has to be related to the syllabus if you are making it for teachers. Otherwise, they won't use it.* (theme 'future toolkit should fit the pedagogical structure of the school')

A2: *If your game looks a bit boring than the other ones, then they're going to be using another ones*. (theme 'future toolkit should be motivational to interact with')

D3: *Internet connection is mostly unreliable. I'm very angry about it <...> I mean it will work like once a week*... (theme 'future toolkit should have representation outside of the virtual reality')

The final theme, namely 'future toolkit should fit the pedagogical views of the teachers', is more heterogeneous and includes different views of different teachers on how the product should be realized. However, it was also frequently mentioned from different points of view that were sometimes repeated, so it is included here as well.

Future toolkit should fit the pedagogical structure of the school

One of the first things mentioned within this question in every focus group was the fact that the toolkit should be related to the school syllabus. It was the matter of using it from the teachers' point of view:

> D1: *No, to adapt according to the learning outcomes framework which are going to be developed. Because if it's not related to the syllabus it won't be implemented in schools.*

The reason lies in the fact that, according to the participants, state school teachers do not have time to spend on 'extra' material as they need to prepare students for exams:

> B2: *But he has... he doesn't have to prepare them for the government exam because he's in a church school. Other teachers might not have that and it has to be someone who is willing to spend time to research, for example, even in primary school.*

In the same line of thinking, educators mentioned that the toolkit should be easy to learn and user-friendly. As teachers already have quite a lot on their hands, they might not be willing to spend time on learning a new toolkit (as useful as it may be) if there are more pressing matters:

> E2: *For instance I would like to use the illustrator but I know it will take a lot of energy and a lot of time to learn it <...> It isn't in the core of what I really need to do at the moment so that would mean in order to spend all the time learning it I'm spending less time on something else. <...>*
> B2: *You end up showing a video than actually doing it because for a teacher, to learn how to do it and to show it to them, it will take you ages.*

Besides being related to the syllabus and easy to master, educators expressed an opinion that the toolkit should be a finished product with an option to tweak its features, so that teachers can customize it for their lessons:

> E1: *I would leave it as it is but with the option for an advanced setting then, you know. Not everyone would go for it. But I would always leave the option that if I want to edit something I might.*

> D3: *...or the ability to change questions, for example, like and learning apps.org.*

Finally, an ideal view of the toolkit from a pedagogical perspective was if it could cover the whole topic of some science subject and teachers could use it without the need to look for extra materials:

> E2: *So in that case if I were a primary teacher or a secondary middle school teacher teaching science what I would definitely use is if you have to create scenarios where I could go kind of to a whole topic.*

Future toolkit should be motivational to interact with

Apart from the concern that teachers might not use the toolkit, participants talked a lot about the interests of the potential primary users – students. Thus, the second big theme that arose in the discussion of the future toolkit properties concerned children's point of view. Educators thought of several ways how they might make the product interesting for the younger generation.

First of all, participants mentioned that the toolkit should have different levels because one topic can be interesting for some kids but boring for others depending on their abilities:

> B1: *There should be grades, different grades, levels, different levels.<...> there was a particular student who told me during the break time, I like this game, she was showing me the tablet. But there was a friend who said, no I don't like this game, it's too easy. So I believe that the game should be... for different levels.*

Some educators even mentioned that it could be motivational for students and at the same time attractive for teachers if there is a challenge to get from one level to another:

> A2: *Or for example if there is something that you go from one level to the next like to go from this level you finish but to start another one you have a multiple choice question and that could be something which...*

At the same time, several focus groups mentioned the importance of blocking some areas of the toolkit if it is to be used at school. As it was mentioned, kids might get bored if they are supposed to do the same thing at school after already doing it at home. So there should be a clear division:

> D2: *I don't know what's best. But for sure doing it in class I don't think it should be available freely at home.*
> A2: *Because the thing is as a teacher if the kids... let's say you have five kids from a class that have already done that. And you've prepared that lesson in this way and you know that they've done it before...*

However, if some children can get through the same topic very fast there should be a possibility for them to do it at different levels while other students are catching up:

> E3: *Or harder level...*
> D3: *Or harder level, so while x is still doing level a, b is still learning.*

One of more general points regarding the future product was that it should be diverse. Students come to the lesson and expect to be surprised – only in this case they will be interested:

> M: *Sure maybe more ideas about what exactly you want to see in it? Is it like a series of tests, games, quizzes, trivia, cartoons..?*
> D3: *I think everything. Because when you go to class and surprise them... if it's always a trivia – no.*

Another idea expressed by several participants was that children may be motivated to try the toolkit if it inspires them. One of the ways to do it is to base it on a story relevant for young people:

> C1: *I think it would be built on a story…*
> E1: *Or characters.*
> C1: *Characters...*
> D1: *Something modern*

Another way would be to show students some role models they can look up to. It does not have to be celebrities but it can even be successful scientists of their age:

> D3: *I think that the success of code.org <...> is in getting those motivational videos that we use in class. Of course you get Bill Gates talking it's not something that can be easily done but my students were just as motivated when they saw young people their age talking enthusiastically about the topic.*

Last but not least, a lot of participants advised to pay attention to the design. The future toolkit should be competitive on the modern market and make a good first impression:

> E2: *If you have a budget and you need to distribute the budget I would put a lot of budget into design because, obviously, you can have a good app but if when you see it, it is a bit dull and not very creative and colourful you won't advertise but if it's very simple but it's very beautiful then I would probably be curious to use it.*

> D2: *Maybe you have an option of different environments.*
> M: *Environment in which sense?*
> D2: *I don't know how you plan to do but it's not like the same background, I can have different options. So if it's technology, it's this kind of background... and then if it's...*

Future toolkit should have representation outside of the virtual reality

One of the popular ideas within Question 5 (features of the future toolkit) was that this virtual product should somehow lead students back to the real world. Participants suggested several ways of doing it, including: some part of the puzzle cannot be solved without a real life experiment or it would be more interesting to see something in the reality:

> D1: *Maybe if the game that might be developed can…. so you're tapping into the modern through the virtual environment and then the missing curiosity part would lead them back to the physical environment ...They have to discover things...*

> A2: *I don't know whether it will work but it can be... If they're doing something sort of virtual and you can have something related to this thing that they can do at home, like home items that physically that they can get it from the kitchen including that... like even make before parents or teachers to do... I think that would help. So even in that way we got the virtual one but we're also providing if you want you can do that which is an actual thing.*

The educators explained why they insisted on referring children back to the reality by saying that there are certain skills that are necessary and cannot be taught by a computer: social interaction and manual labour. These theme was already discussed in the question about advantages and disadvantages of the use of digital tools in class when teachers were insisting on the importance of the real world together with the virtual one. Their focus on the reality matches their ideas for the toolkit:

> D1: *And my the fear is that technology would limit social interaction. <...> And ultimately science is communicating with others. So if you have to eliminate social interaction you would be eliminating part of it.*

> B2: *In certain jobs it's about technology and thinking etc, but in other jobs you need to use your hands so you can't just not focus on those in class.*

As we have seen from the previous chapter on advantages and disadvantages of the use of digital tools in class, teachers were concerned about frequent problems arising when using technology – unreliable WiFi connection. It is noteworthy that their concerns were reflected in the requirements for the future toolkit we asked them about. When they were asked about technical requirements, they asked it to be available offline due do the connection problems:

> A3: *Available offline. Maybe you can download so that you can use it on offline.*

More to that point, educators also said it would be useful if the toolkit could be complemented with something more tangible that students and teachers could use for a reference, e.g., a resource pack, printable materials, etc.:

> E2: *And perhaps maybe at some point link it to something more tangible. Perhaps, you could have one of the scenarios which would be accompanied by a resource pack where you manage this scenario just to keep to it. Or you would actually have a resource pack with different tangible... which after they can observe closer.*

> A3: *Printable materials that can go with the activities that you've done. Maybe even if they have created something themselves through a game or a task, maybe a design or flowchart that it can be extracted from the system, printed and given to the students as notes or as a reference.*

Future toolkit should fit the pedagogical views of the teachers

The final notes on what should be included in the future toolkit concerned teachers' pedagogical views. Several of them suggested that group work is more effective and even healthier (like social interaction) than individual work so such a mode of studying should be taken into account when designing the product:

> E1: *Group work. So they can work as a team even if the game is connected within 4-5 kids. It can take the whole classroom but they can make their own groups or they can work individually. but I think the more we can involve more people, group work…*

B1: *It's more healthy.*

A2: *I think what something that they like is joining together playing the same thing so it's multi user...*
D2: *Multiplayer.*

Some teachers also said that the toolkit should be socially inclusive, i.e. allowing people with different (especially low) abilities to take part in it together with their classmates and develop in this way:

D1: *To be also socially inclusive as well because not everyone might be... to be socially inclusive, so that people with different abilities can participate*.

Finally, different participants suggested that the toolkit should take care of different senses (not only sight). According to them, not all kids can learn visually:

E3: *Since I teach low ability children, I tend to focus on some of the senses. For example, not all students learn Mathematics through just 'think'. So I have to focus tasks on touching and hearing, for example. Senses, too, make an important... You know, you get to know your students and you observe how better they learn and in which way they do learn better.*

However, even those students who are visual learners should also develop other senses, or learning styles:

E2: *And maybe it should be also multi... using more than one sense so you would see, you will listen to different sounds and you can do something, so kinesthetic as well. It would help to not just be visual.*

4.5. Summary of the Results

This is a short summary of the results presented in the previous chapter. It will present the answers to the three research questions raised at the beginning of this work:

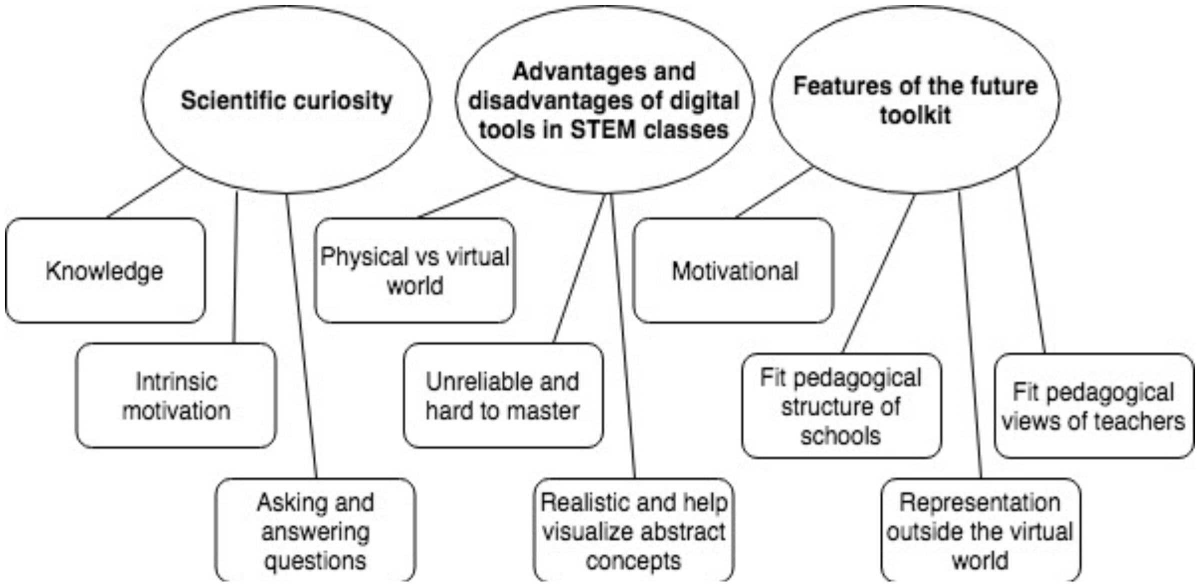


Figure 3. Summary of Results

What do STEM-subjects teachers understand by "scientific curiosity"?

According to teachers, scientific curiosity appears to have a three-step formula: first, you wish to know how things work, then you ask questions about it and then you try answer them by various methods and obtain new knowledge.

What are the advantages and disadvantages of the use of digital tools in STEM classes?

The main advantage of using digital tools in STEM classes mentioned by teachers was that they help visualize certain material. According to the teachers, a lot of software is very realistic, so it helps explain difficult abstract concepts and to grab students' attention.

As a disadvantage, teachers stated that digital tools are often unreliable: the Internet connection may break, the hardware may be outdated, etc. It is also a problem, in their opinion, that a lot of students and teachers are still IT Illiterate so it is hard to use the tools for them. Finally, they say that most of the teachers would be reluctant to learn new software if it is time-consuming.

On a more general note, teachers mentioned that despite the fact that children should get good technology education, it is important to remember that the real world is primary to the virtual one. They insisted on the good balance between the two of them.

Which features would they like to see in the future toolkit?

Numerous ideas on the possible features of the future toolkit could be combined into four big categories.

First of all, teachers would like the toolkit to fit the pedagogical structure of the school: it should be a finished product that is related to the syllabus, user-friendly and covering the whole topic of some subject.

Secondly, teachers want the toolkit to be motivational for their students to interact with: it should have different levels and a challenging task to move from one to another; some areas for classroom use should be blocked so that students would not be bored on the lesson; it should have different kind of tasks, be inspiring, and have a competitive design.

Thirdly, teachers suggest that the toolkit should have representation outside of the virtual reality. They offered such ways of doing it as: creating some tasks in the toolkit that could only be solved by real life experiment; making the toolkit available offline so that it would not be dependent on the Internet; complementing the toolkit with something more tangible, e.g. the resource pack.

Finally, teachers would prefer the toolkit to fit their pedagogical views. They think that the toolkit should have a possibility of group work as it seems healthier to them; it should also be socially inclusive, especially for low ability students; it should involve different senses as not all students are visuals and even visuals should develop other learning styles.

6. Discussion

6.1. Discussion of the Results

The purpose of this study was to investigate teachers' views on the use of digital tools to foster students' curiosity in STEM subjects. With the help of focus groups, I found out teachers' opinions regarding the definition of scientific curiosity, advantages and disadvantages of the use of digital tools in class and the specific requirements they have towards the future digital toolkit.

It is noteworthy that teachers' conceptual views on the digital tools in general fit their specific requirements for the toolkit. E.g., they said that the Internet connection is unreliable, therefore the toolkit should be available offline; or they commented on the importance of the real world together with the virtual one, therefore their focus on reality was reflected in the features of the digital toolkit. It shows the consistency and coherence of teachers' opinions throughout focus groups and, again, might indicate the reliability of the results.

Another interesting point was that teachers' definition of scientific curiosity did not vary much throughout the focus groups, which means they have quite a unified idea of the concept despite the contradicting presentation of "curiosity" in the literature. It might indicate that teachers understand curiosity too limitedly (see "Connection to the Literature" part below).

The results also point out that a well thought-through design fitting pedagogical structure of schools and pedagogical views of teachers are essential for any innovation to be implemented in an educational institution.

Interpretation of the Results
The theoretical framework chosen for this research was social constructionism which implies some level of subjectivity. In other words, "data and findings presented in any research report reflect and represent only partial views that are always filtered through the researchers and participants' subjectivities that are produced in a sociopolitical setting at a particular historical time" (Puig, Koro-Ljungberg, & Echevarria-Doan, 2008). That is why it is impossible to detach the findings of this study from my background and previous experiences, as well as from background of other researchers taking part in the CURIO project and influencing some of the research design decisions (e.g. questions for focus groups). However, the method of analysing the data – thematic analysis – was chosen to be inductive, i.e. it is strongly connected to the data (Braun & Clarke, 2006). That means that themes were data-driven and the level of interpretation was not so high as it aimed mainly at structuring the answers of the participants.

Relevance for Education
The present research can be used as a set of practical guidelines for a design project similar to CURIO. It shows "what teachers want" in a very general way so it might have a variety of applications. Since most of literature concentrates on assessing educational reforms after they were introduced (Johnson, Reinhorn, Charner-Laird, Kraft, Ng, & Papay, 2014), a lot of problems concerning their exact implementation in class are revealed too late. The present thesis describes teachers' specific requirements to the new tools introduced in class. In this

way, it could be a starting point for researchers interested in the critical review of educational innovations before they are implemented which would help to avoid certain practical problems.

It can be also interesting to educational researchers that want to investigate the topic deeper or in a different area and improve the results. Even though this research was aimed at Malta, its results could be relevant for other countries that have similar education system and the state of facilities (e.g. countries with very developed IT in education might disregard the part where technical problems are considered).

Connection to the Literature
As it was already mentioned before, one interesting finding concerned the understanding of the term "curiosity" in focus groups. As it was pointed out in the Key Concepts chapter of this thesis, curiosity is generally agreed to have two types: state and trait curiosity, also known as "situational" and "dispositional" curiosity (Guthrie, 2009). Despite the fact that I did not specify to teachers which kind of curiosity we were interested in, their answers implied the understanding of curiosity as a trait coming from intrinsic motivation. That might point to the fact that teachers are more prone to believe that some students are more predisposed to being curious rather than curiosity could be developed by outside world triggers. On the one hand, it is disappointing as it would mean that, in teachers' opinion, no digital toolkit could arouse curiosity in some students. On the other hand, it is not very convincing as teachers themselves stated in focus groups that there are no "boring" topics because "we always find a way how we can interest, make it enjoyable". It may seem that teachers contradict themselves. However, this situation can also be a result of the fact that the curiosity question was asked first and teachers could interpret it as a "trait curiosity" question, while they could change their view with the subsequent questions and answer them with a different idea in mind.

Another interesting point regards Collins & Halveson's (2009) book that mentions customized education available anywhere/anytime (online) as a modern trend of digital tools in education. It indeed seems true as participants of the focus groups were actually concerned with the technology taking away the real life communication ("*And my fear is that technology would limit social interaction*") and were insisting that group work is more healthy and that the physical world is still primary over the virtual one.

Future Research
This research produced design guidelines for the CURIO project from the point of view of the teachers. However, teachers will not be the only end users of the future CURIO toolkit. The project needs to conduct further research such as, e.g. focus groups with the students (other perspective end-users) and thorough state of the art helping them foresee possible issues with e.g. implementation from the government point of view.

Results have raised some questions for future research: Do teachers from all types of schools share the same opinion on the use of digital tools in class? Do the subjects of teachers (e.g. Maths vs. Biology) influence their opinion? Do all schools have sufficient equipment to participate in this research? Did the structured focus group questions limit teachers in the expression of their opinions?

6.2. Discussion of the Methods

The method chosen for this research – focus groups – fit the theoretical perspective of social constructionism and the time constraints of the project setting perfectly. It provided rich data in a short period of time and allowed for different opinions to be discussed "on the spot".

However, there were still some limitations:

Number of moderators

A high number of moderators might change the way participants interact with each other. As Morgan (1997) warns researchers to pay attention to moderator involvement not to make it too obstructing for the discussion, the issue was taken seriously. If participants feel (even unconsciously) pressured by a big number of strangers in the room, they might be less confident, less open, less talkative. As we had quite a few moderators (3 people) for quite moderately-sized focus groups (5 people), we wanted to avoid these possible drawbacks. For that reason, all the moderators had an informal conversation with all the participants before the actual focus groups, participated in the warming up exercises and tried to make feel everyone comfortable. During the actual focus groups, only the primary moderator (the author of this thesis) was directly interacting with the participants. Other moderators were sitting at the back of the room taking notes and were not involved in the process.

Sampling strategy

This research is quite diverse in terms of age, gender, years of experience and subjects that participants teach. However, it was not perfectly balanced. Females prevailed males by 50%, most of the participants were under 40 years old, such subjects as Technology and Engineering were not well presented, and types of institutions were quite limited – lacking private and church schools (see Appendix 2). On the other hand, state schools are prevailing in Malta, so we targeted the main audience.

Apart from that, one might say that people who chose to participate in these groups were volunteers which suggests they were initially more interested in such kind of a project (a phenomenon often referred to as 'self-selection bias'). On the other hand, those are the people who are more likely to interact with the future product. Besides, discussions within focus groups revealed that some of the participants were not digital enthusiasts but still were interested to participate which gave us a variety of opinions.

Quality of questions

In terms of quality, the questions created for this research seemed to capture all the main themes we were interested in but only for *most* of our potential users. In the course of conducting focus groups, we noticed that the following issues were overlooked: students with low abilities or health impairments, the state of digital literacy among teachers and students in Malta, resources available in Maltese schools. Fortunately, we were still able to tackle some of these questions during the focus groups and we will take them into account in the future research.

Besides, by hindsight it seems that there was a need for one more question that would combine all the topics discussed before and would specifically reveal teachers' opinion on how digital tools can help foster curiosity in STEM. Instead, teachers were asked questions that constituted parts of the main one, so a degree of interpretation had to be applied to construct a full picture.

7. Conclusion

The aim of this study was to investigate teachers' views on the use of digital tools to foster students' curiosity in STEM subjects. The aim was achieved by answering three research questions. The results of this study indicate that STEM-subjects teachers understand scientific curiosity as a positive trait that leads to asking questions, obtaining knowledge and is coming from within you. They are also in favour of using digital tools, although moderately, in class if they function properly and easy to master as they help visualize learning material. They also hope that the future toolkit will fit the pedagogical structure of the school, will be interesting for their students, will not be completely detached from the reality and will fit pedagogical views of the teachers such as using group work and different learning styles.

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Appendix 1. Demographic Data Form

Your code name: ____

Gender:____

Your age range (underline the correct option):
below 20, 20-30, 30-40, 40-50, 50-60, 60-70, over 70

How many years have you been working in science education/science communication?
____

Which subject(s) do you teach/ have you taught in the past?
____

Type of school/ institution you are working in:
____

Additional comments: ____
____

Appendix 2. Summary Table of Participants' Demographic Information

	Chosen code name	Gender	Age range (y.o.)	Work exp. (years)	Subjects taught	Institution
1.	Mary Rose	f	30-40	17	Primary science	State school
2.	Sandro	m	50-60	25	Primary science, design and technology	State school
3.	John	m	40-50	19	Primary subjects (incl. Science)	State school
4.	Isabel	f	30-40	4	Primary and science	State school
5.	Chris	m	40-50	5	Maths, Science	State school
6.	-	f	30-40	7	Maths	Non-formal education institution (NFEI)
7.	-	f	20-30	2.5	Maths, Physics	NFEI
8.	-	f	20-30	1.5	Chemistry	NFEI
9.	-	m	20-30	2	-	NFEI
10.	-	m	20-30	12	Biology, Science	NFEI
11.	-	f	40-50	20	Maths	State secondary school (SSS)
12.	-	f	30-40	11	Maths, Engineering	SSS
13.	-	f	30-40	12	Maths	SSS
14.	Hopper	f	40-50	17	ICT, Computing	SSS
15.	Fibonacci	F	30-40	16	Maths	SSS
TOTAL		**m - 5** **f - 10**	**20-60**	**1.5-25**	**Maths – 7** **Science – 6** **Design and Technology – 1** **Biology – 1** **Engineering – 1** **ICT – 1** **Chemistry – 1**	**State Schools – 10** **Non-formal education institution – 5**

Appendix 3. Information Letter

Information Letter

Institute of Digital Games
University of Malta
Msida, MSD2080
Malta

Dear participant,

I am a student reading for a Master in Information Technology and Learning at the University of Gothenburg, Sweden, under the supervision of Wolmet Barendregt. In collaboration with the Institute of Digital Games, University of Malta, I am working on a part of Erasmus+ project "CURIO - A Teaching Toolkit for Fostering Scientific Curiosity" (project code 2017-1-MT01-KA201-026985) under the supervision of Dr Stefano Gualeni. CURIO is a three-year project aimed at developing a digital toolkit to stimulate pupils' curiosity in scientific topics. The toolkit will merge technical innovation and new pedagogical opportunities to create a playful, virtual world where pupils can engage their scientific curiosity in a gamified, virtual environment.

I would like to invite you to participate in this project by taking part in a focus group discussion.
Your participation in this study is very important for us as you could potentially be immediate users of the CURIO toolkit. That is why we would like to hear your opinion and discover your ideas beforehand.

Your participation in the study entails a video- and audio-recorded semi-structured discussion as a part of a focus group consisting of STEM (science, technology, engineering, and mathematics) subjects teachers/science communicators. The discussion will last approximately two hours. Questions that will be raised concern students' interest in STEM subjects, definition of scientific curiosity, challenging topics in STEM subjects, digital tools for teaching STEM subjects, etc. You do not need to prepare for this discussion in advance as we would like to hear your spontaneous ideas that would arise from talking to other participants.

There are no identified risks from participating in this research. Participation is completely voluntary and you are free to withdraw from this study at any point in time should you wish to do so. Your identity will remain anonymous as will the name of the organization you are working in. Any sensitive information that might be revealed during the focus group discussion will be treated in strictest confidence.

Further information regarding this research can be obtained from me via email margarita1807@mail.ru or phone number +35679340424. Further information regarding CURIO project in general can be obtained from my supervisor Dr Stefano Gualeni via email stefano.gualeni@um.edu.mt at the Institute of Digital Games, University of Malta.

I look forward to working with you and thank you in advance for your time and support.

Kind regards,

Margarita Iashchina

Appendix 4. Consent Form

Informed Consent Form

Research title: Teachers' view on the use of digital tools to support students' interest in STEM subjects
Project name: CURIO - A Teaching Toolkit for Fostering Scientific Curiosity
Project code: 2017-1-MT01-KA201-026985

Researcher: Margarita Iashchina
ID: 0176598A
Address: Institute of Digital Games, University of Malta, Msida, MSD2080, Malta
Email address: margarita1807@mail.ru
Contact phone number: +35679340424

Supervisor: Dr Stefano Gualeni
Institution: Institute of Digital Games, University of Malta

Declaration by Respondent:
I have read and understood the information provided by Margarita Iashchina in her introductory information letter concerning the research in caption, and I have had the opportunity to ask questions and to obtain any additional information I requested about this research.

I hereby offer my full informed consent to participate in this research and grant permission for the focus group discussion to be video- and audio-recorded and transcribed to facilitate data analysis, on the following conditions:

- ✓ The data collected will only be used for the purposes of this research and will not be shared with any third parties
- ✓ Confidentiality will be guaranteed and data presented in the research will be anonymised
- ✓ I may refuse to answer/discuss any of the questions asked
- ✓ I may withdraw from all or part of this research at any time
- ✓ I have no objection to the photos being taken during the session

Participant's Name:

Participant's Signature:

Date:

Appendix 5. Questions for Focus Groups

Focus group questions

1) *Could you write down a definition of scientific curiosity (curiosity linked to STEM topics)?*

2) *Could you discuss your definition in small groups of 2-3 people for about 3 minutes and then say what you came up with?*

3) *Which are the science topics that arouse scientific curiosity in children – how and why? Which are, on the contrary, the science topics that don't arouse any curiosity, why?*

4) *Have you ever used any digital tools to support your work? If yes, which?*

5) *As you know, CURIO plans to develop an online digital toolkit for children and teachers. What would you like to see in this toolkit?*

6) *Can you provide any examples of excellence that link curiosity, STEM topics and digital tools?*

Appendix 6. Design Guidelines for the CURIO Project (from the final report on focus groups)

This part attempts to give recommendations concerning design solutions to the developers of the future CURIO toolkit on the basis of focus groups' results. A lot of technical details are based on the results of Question 5, so refer to that part for more details.
Future users (in Malta). According to the results of our focus groups, potential CURIO users are primary and secondary school teachers between 30 and 40 years old, mostly females, having average (sometimes – above average) digital literacy skills, familiar with computer games and most online educational resources. They use interactive white board and computers in class quite regularly and feel positive about using technology at school.
Place and time of possible use. The toolkit should be available both at school and at home (note that in this case some areas should be locked). Teachers are inclined to dedicate 10-20 minutes of the lesson to the online support if it is relevant to the syllabus.
Platform. For primary school it could be tablets (they are provided by the government), for secondary schools the situation is more complicated. It should be either something that teachers can make use of with the interactive white board (PCs are scarce) or something available offline (unreliable Internet connection). It is rare that students have both Internet and PCs available to them simultaneously.
Design (visual). Well-done, colorful, realistic. It should be competitive on the modern market.

Technical features

- Should be a ready-to-use product but have adaptable content.
- Should have different levels according to age/abilities.
- Should have a possibility to have group work or a multi-payer mode.
- If used at home – some areas should be locked.
- History of activities and progress should be visible for students and teachers.
- Should be available both in English and Maltese (simple and short language).
- Could have links to other resources.
- Can make use of different senses (touch, hearing, sight).

Content

- Should be diverse and make use of different activities: videos, quizzes, games, etc.
- Should relate to the real world and encourage kids to explore.
- Should be directly related to school syllabus.
- Should have "sense of fun".
- Might have reference to local (Maltese) scenarios.
- Might have printable materials generated after class or a resource pack before class.
- Might have cross-curricular links connecting different subjects.
- Might have an immediate feedback and competitive mode.
- Might have role models that give testimonials and motivational videos.
- Might have some storyline or interesting characters, bubbles with "interesting facts".
- Might have reward in terms of points that children can "spend" to buy something else in this application.