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Overcoming obstacles when integrating ICT in STEM teaching for disadvantaged children

An interview study on the obstacles of using computers in STEM and how an experience of a computer-integrated lesson can affect teachers' behavioural intention

Master's thesis in Learning and Leadership

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DEPARTMENT OF COMMUNICATION AND LEARNING IN SCIENCE
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Abstract

In many places in the world, poverty is still widespread, and access to technology is low. One part of poverty reduction could be to increase ICT literacy in disadvantaged communities. This study aims to identify obstacles to integrating ICT in the form of computers in STEM teaching with children from disadvantaged communities, and to examine the effects an experience with a computer-integrated lesson can have on teachers' behavioural intention. This was done by conducting semi-structured interviews with teachers at a school in South Africa, and by conducting computer-integrated lessons which the teachers observed. The findings were used together with a framework called the *Unified Theory of Acceptance and Use of Technology* to explain behaviour, and thereby identify obstacles. The results showed that resources and knowledge were the major obstacles to computer integration. The effects of an experience with a computer-integrated lesson were that performance expectancy increased, effort expectancy decreased, and that the teachers reported an increase in intention to incorporate computers more in their teaching. The study concludes that facilitating conditions such as resources and knowledge is an obstacle, and that an experience can have a significant positive effect on teachers' intentions. An effective method for increasing computer usage in STEM teaching could therefore be short continuing education for the teachers, as well as providing schools with the necessary resources.

Keywords: ICT, STEM, Education, SES, Disadvantaged communities, UTAUT, Computer literacy, South Africa.

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William Blomström, Jonatan Holmström, Gothenburg, May 2023

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

CAT	Computer Applications Technology
DBE	Department of Basic Education
EE	Effort Expectancy
FET	Further Education and Training
FC	Facilitating Conditions
GET	General Education and Training
ICT	Information and Communication Technology
IT	Information Technology
PE	Performance Expectancy
SES	Socioeconomic Status
SI	Social Influence
STEM	Science, Technology, Engineering, and Mathematics
TIMSS	Trends in International Mathematics and Science Study
UTAUT	Unified Theory of Acceptance and Use of Technology

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1
Introduction

In the last century, *Information and Communication Technology* (ICT) has gotten an increasingly important role in society. Today, most people, at least in the Western world, have a personal computer (OECD, 2023). Chances are that you as a reader are using a computer right now. One can argue that it is difficult to overestimate the importance of being able to use a computer in modern society.

According to Sida (2019) there are four dimensions of poverty: resources, opportunity and choice, power and voice, and human security. All of these have, to some degree, direct connections to access, knowledge about, and experience with ICT. Lack of access to, and knowledge about technology, can therefore be argued are part of what makes someone poor. There are also indications that ICT is a driving force for economic growth. In a working paper from the European Central Bank, Labhard and Lehtimäki (2022) found that digitalisation, in the form of broadband subscriptions and internet users, has a significant positive effect on economic growth. Vu et al. (2020) also saw strong indications that ICT, for example computers, smartphones, the Internet, and radios, have a significant positive effect on economic performance. Adera et al. (2014) found that ICT can have a direct impact on reducing poverty.

In many places in the world, ICT access is still limited. Statistics from the World Bank (n.d.) shows that internet access, which could be a good measurement for ICT access, is very low in some countries in the world. It is therefore important to bring knowledge and experience with ICT to people living in difficult socioeconomic situations. South Africa is one country with relatively low access to ICT, and with high economic inequality. It ranks highest on the Gini-index, which measures income and consumption inequality (World Bank, 2014). In countries like South Africa, one opportunity to increase ICT literacy is for the school system to take responsibility and provide the children with ICT skills.

For these reasons, this study aims to create opportunities for children with low access to ICT at home, who might not even have electricity, to learn ICT skills through the school system. This will be done by conducting a field study in South Africa, and identifying obstacles which might hinder the integration of ICT in the form of computers in STEM teaching. Furthermore, the study will investigate how an experience of a computer-integrated lesson might affect teachers' intentions to incorporate computers more in their STEM teaching. The objective is that the children could learn computer skills through the means which are already available to them at the school, while not requiring extra time from the curriculum.

1.1 Background

ICT has been used in education for a long time. In the 1940s the first computers were introduced in education at University level. The use of computers continued, and in the late 1960s the usage rapidly increased. The role computers pose in education and society is greater today than ever before (Molnar, 1997; Wellington, 2005; United Nations, 2021). There is still a debate about whether this use of ICT in the form of computers is good or not in education. Livingstone (2012) questions the validity of the research stating that ICT benefits learning. They also question whether the role of ICT should change education or be a part of traditional teaching, as well as whether the change ICT entails in society and education is something beneficial or detrimental to children. Despite this critique, many would argue that ICT in education has many benefits. ICT promote active learning, equality, skills beyond learning, makes education more attractive, benefits educational institutions, and improves learning and teaching quality (Foutsitzi and Caridakis, 2019; Fu, 2013). The argument that ICT is something good for both teachers and learners prevails.

ICT can have other benefits as well, for example with regard to underprivileged children. Vekiri (2010) states that children with low socioeconomic status (SES) generally have lower self-efficacy using ICT, and that ICT usage in school is especially important for these children. This is strengthened by Scherer and Siddiq (2019) who found a correlation between the SES and ICT literacy of children in k-12 schools. Bovée et al. (2007) found that children with lower access and experience with computers had a more negative attitude towards using computers in school. Meanwhile, Hambira et al. (2017) reports that ICT usage with children from disadvantaged communities had a positive impact, that enjoyment, hope, and confidence were boosted, and that there was no increase in anxiety. For children with low SES, it seems that the incorporation of ICT in education would be beneficial, not only from a learning perspective. It is therefore important to understand how ICT, perhaps in the form of computers, could be integrated more in underprivileged parts of the world.

1.1.1 South Africa's educational system

South Africa is a country with large inequalities, and as mentioned earlier it ranks number one on the Gini-index (World Bank, 2014). An explanation for this might be its past of colonisation and racial segregation. The political system of apartheid was implemented in 1948. It classified the population into four groups: Black, White, Coloured and Asian. In practice, the system meant that the white population received several privileges, while the others were discriminated against. Apartheid ended in 1994, but as the Gini-index shows there is still big inequality in South Africa (Encyclopaedia Britannica, n.d.). In the report *Broken and unequal: The state of education in South Africa* written by Amnesty International (2020) the inequalities in South Africa's educational system are pointed out. One concern which is addressed is the unequal distribution of computers.

In South Africa, the Department of Basic Education (DBE) is responsible for all schooling below university level (Department of Basic Education, n.d.). They have divided the schooling system into two phases: the *General Education and Training Phase* (GET), and *Further Education and Training Phase* (FET). GET is from grades K-9 and FET is from grades 10-12. The main difference between the phases is the exposure to different subjects. In GET all subjects are mandatory whereas in FET there is a total of seven subjects of which four are mandatory and three are optional (Department of Basic Education, 2021b).

Throughout schooling in South Africa there are some subjects that require or recommend ICT in the curriculum, for example, *Computer Applications Technology* (CAT) and *Information Technology* (IT) (Department of Basic Education, 2011a,b). Both of these are elective courses in the FET phase, which means that only the students who select them will be guaranteed to gain computer knowledge in school. In an action plan written in 2015 the DBE declare that the amount of schools that offer the these courses is a good estimate of the number of schools that provide the learners with access to computers. In the report, the number of schools that offered the courses for grade twelve learners was 24 % (Department of Basic Education, 2015). The DBE does however have other ways of trying to make ICT incorporated in the educational system. In 2004 the South African Department of Education, which since then has become the DBE, released a white paper called *White Paper on e-Education: Transforming Learning and Teaching through Information and Communication Technologies (ICTs)* (Department of Education, 2004). In the white paper, they make a case for how important it is for South African schools to develop their use of ICT in education and thereby transform into *E-schools*. E-schools are physical schools that meet certain requirements such as ICT access, learners that use ICT in their education, and competent leaders who use ICT for management. To conclude, the white paper manifests that the DBE has a clear goal to incorporate ICT into the school system. Therefore their goals for integrating ICT in education and the goals of this thesis fit well together.

In 2021 42 % of the 23,276 public schools had computer centres (Department of Basic Education, 2021a). In the Eastern Cape province, only 11 % had computer centres. The *Trends in International Mathematics and Science Study* (TIMSS) from 2019 measured the proportion of schools in South Africa that provide access to computers for mathematics education. TIMSS state that 8 % of South African grade four students had access to computers for mathematics education. For grade eight, 9 % had access to computers for mathematics education (Mullis et al., 2020). Internet access for teaching was only 20 % in 2021, which is problematic if the computer centres that exist should be used properly (Department of Basic Education, 2021a). When it comes to computer access in South African homes 27,3 % owned one or more computers in 2021 (Department of Statistics, 2021).

In conclusion, it is clear that computers are not available to all learners in South

Africa, especially not in their mathematics education or at home. Internet connection is a major problem if computer-integrated teaching is going to be implemented. The DBE is working toward the integration of ICT for all learners, but they still have far to go. Even if there are subjects that include ICT such as CAT and IT, it is not available at all schools and all learners do not take these courses. Using computers in STEM teaching would mean that all students got experience with computers.

1.2 Purpose

The purpose of this study is to increase the ICT skills of underprivileged children through the school system, as this would be beneficial for these children. To achieve this, two aims were created. The first aim of this study is to identify the obstacles to using ICT in the form of computers in STEM teaching in a setting where the learners are likely to have little to no access to computers outside the school environment. The second aim is to measure how an experience of a computer-integrated lesson can affect teachers' intentions to incorporate computers more in their STEM teaching.

1.3 Specification of the research question

To reach its purpose the study aims to answer the following questions:

1. What obstacles are there for the teachers to use computers in their STEM teaching in a context where the learners have low access to computers outside the school environment?
2. How can an experience of a computer-integrated lesson affect the teachers' intentions to use computers in their teaching?

1.4 Literature review

Hwang et al. (2022) used a model called the *Unified Theory of Acceptance and Use of Technology* (UTAUT) model to examine key factors influencing computer usage amongst children from disadvantaged communities in a developing country. Their findings showed that performance expectancy (PE), social influence (SI), and facilitating conditions (FC) were the main factors affecting whether the children, who were enrolled in an ICT program, used the computers for learning or not. They found that while PE had an effect, SI and FC were stronger determinants. In their study, it was found that only between 58.6% and 67.7% of children living in urban communities had access to computers at home, and that children in rural areas had even lower access. For this reason, they state that lack of access to computers could have a negative impact on usage. SI was argued to have a significant effect as well, especially if people of influence, amongst which they mention teachers, believe they should use computers for learning. Furthermore, they found that FC had a significant impact. They argued that the children's environments were of great importance, as well as their knowledge of computer usage. Finally, they address the role of the teacher as an influence, and suggest that if teachers emphasise how computer usage could benefit learning, the children would be more likely to use computers, and thus improve the necessary ICT skills. They also state that teachers could encourage students to use school computers after hours if a limited number of computers are available during school hours.

Chiao and Chiu (2018) studied the relationship between SES, ICT usage, and academic achievement in Southeast Asia and found that the way ICT is used is of great importance. They found that ICT use for social interaction and information retrieval could, at least in the context of their study, widen the achievement gap between students with high and low SES. However, they also found that ICT use for learning could reduce the gap, even if this correlation was weaker. They conclude that simply providing ICT for students with low SES is not necessarily helpful, its utilisation is also of importance.

Saal et al. (2020) also used the UTAUT to investigate the factors affecting teachers' use of ICT in mathematics education. The study was conducted at two South African schools in disadvantaged communities. The teachers they interviewed had a positive view of the performance ICT can have in mathematics education. They saw it as engaging and good for learning. The teachers found the use of ICT quite hard and they had to put in effort to use it. The study found that facilitating conditions such as proper WiFi connection and access to IT technicians are important to the implementation. The main reason the schools used ICT was social influence. The municipalities had chosen these schools as ICT-pilot schools and therefore the principals encouraged the teachers to use ICT in their education.

Chigona et al. (2010) studied ICT integration in disadvantaged communities in South Africa, and focused on what obstacles there might be for teachers to adopt ICT in their teaching. They state that for ICT to reach its full potential, technology needs to not just be available, but needs to be integrated into the pedagogical processes of the school. Furthermore, they state that most teachers, after some initial training, thought that ICT could benefit teaching and learning. The study identified several obstacles to ICT integration. They argue that the teachers' ICT skills were important. If the teachers did not feel competent enough to use ICT, they were less likely to do so. The most prominent obstacle was resources and facilitating conditions. They state that schools without technical support were less likely to integrate ICT, that this was enhanced in disadvantaged communities, and conclude that if ICT is to be used effectively, enough resources have to be available. Another identified obstacle was the ICT skill of the students. They found that if the students were not confident with a computer, time had to be taken from the subject teaching to educate them on how to use the computer. Another aspect which is addressed is the willingness of teachers, and they state that the economic situation of a school might make ICT integration unavailable, despite a positive teacher willingness. Finally, they conclude that simply providing hardware likely leads to ineffective use, as not all schools with enough resources felt competent enough to use it.

Buabeng-Andoh (2012) did a literature review of factors influencing teachers' adoption of ICT in their education. They conclude that for effective integration, teachers must perceive the technology as better than previous practices, fit with their own values, and be easy to use. They also state that many teachers are unlikely to integrate ICT into their teaching by just reading or talking about the benefits of ICT, but must rather observe the benefits themselves. Furthermore, they conclude that teachers must be confident that ICT will make their education more interesting, fun, and beneficial for the students. Finally, the study addresses potential obstacles for teachers to integrate ICT. These include a lack of teacher ICT skills, a lack of ICT infrastructure, and restrictive curricula. They suggest that knowing the extent of these obstacles could be important for decision-makers to enable ICT integration.

In summary, similar studies as this suggest that the role of the teacher is important, how ICT is used in school matters, teachers' perception of the usefulness of ICT together with facilitating conditions determines if ICT is used, and that teachers' perceptions are more likely to change if they experience the benefits of ICT rather than hearing or reading about them.

1.5 Limitations

The teachers are the study object of this study, therefore no data from the learners were collected. The main reason for this was that the purpose of the study was to understand how computers could be used more, and as the teachers, not the children, were the ones deciding whether computers would be used, it was found reasonable to only study the teachers and their inclination towards using computers. This entails that the children's subject learning and computer literacy were not measured. Furthermore, in order to be allowed to gather personal information consent has to be given by the person in question. For children, this means that parents have to consent. Gathering consent from parents posed a too difficult logistical problem, and for these reasons, only data from the teachers were gathered.

The thesis only included one school and its teachers. The reason for this was mainly a limitation in the available time. Due to logistics, budget, and school terms, the fieldwork at the school had to be finished in four weeks. As the study was expected to require some effort from the school it was important to build good relations with the teachers. It was also expected that each computer-integrated lesson would have to be tailored to each teacher's needs. Furthermore, an important aspect was the context of the school and the children. Understanding this would also require significant amounts of time. For these reasons, only one school was studied in this thesis.

2
Methodology

As one purpose of this study was to describe the obstacles to computer integration in STEM teaching, it was necessary to examine what determined the teachers' behaviour. To achieve this a framework by Venkatesh et al. (2003) called the *Unified Theory of Use and Acceptance of Technology* (UTAUT) was selected. According to this framework, a person's own perception of a number of different factors is what determines the behaviour. This meant that the required data for this study was the teachers' thoughts and opinions. To acquire such data, Esaiasson et al. (2017) suggests that interviews are the best method of data collection. Alsaawi (2014) offers some critique towards interviews as a method of data collection, for example, that it is time-consuming, and that the interviewer might affect the results. Despite this, they also state that interviews are an excellent method when the aim is to describe complex social phenomena, and that it is a very commonly used method, with many benefits, such as flexibility. With this in mind, semi-structured interviews were chosen as the method of data collection.

An important aspect of the study was the context, which was supposed to be a context where the learners had little to no access to computers outside the school environment. Therefore such a context had to be chosen.

The other purpose of the study was to investigate how an experience of a computer-integrated lesson could affect the teachers' inclination towards using computers in their STEM teaching. To achieve this, mathematics lessons were planned and conducted by the authors of this study, while the teachers observed. The natural science teacher did however plan a natural science lesson, which the teacher also conducted themself. After these lessons, the teachers were interviewed again to examine whether any change had occurred.

Finally, the data had to be analysed. Esaiasson et al. (2017) suggests that the *mapping method* is the most suitable option when the goal is to map aspects of a certain phenomenon. Since that was the goal of the analysis the mapping method was chosen. Before using the mapping method the interviews were transcribed and summarised.

In the following sections, the UTAUT framework, the context, the design of the interviews, the experience of a computer-integrated lesson, and the data analysis method will be described.

2.1 Unified Theory of Acceptance and Use of Technology

Venkatesh et al. (2003) created the UTAUT framework by unifying several commonly used theories for explaining user acceptance of new technology in their work. These theories were analysed, their different aspects dissected, and merged into a new unified theory. This new theory was then empirically tested, and was shown by Venkatesh et al. to outperform all other commonly used theories, and has since then been a commonly used method for explaining user behaviour. For this reason, the UTAUT framework was chosen for this study.

The UTAUT framework consists of four main factors which explain user behaviour. These factors are

- Performance Expectancy (PE)
- Effort Expectancy (EE)
- Social Influence (SI)
- Facilitating Conditions (FC).

Performance expectancy is defined as the degree to which a person believes the adoption of a new system would improve job performance. The factor includes aspects such as task effectiveness, productivity, job difficulty, and job quality. Effort expectancy is defined as the amount of effort a person associates with the use of a new system. The factor includes aspects such as the difficulty of learning the system, control of the system, and ease of use. Social Influence is defined as the degree of influence a person experiences from others to use a system. The factor includes aspects such as the opinions of supervisors, management, role models, and to what degree coworkers use the system. Facilitating conditions is defined as to what extent a person believes that the infrastructure, both organisational and technical, is available. The factor includes aspects such as perceived resource and knowledge availability, system capability, support access, and job fit. PE, EE, and SI describe what the framework calls *behavioural intention*, which together with FC describes *use behaviour*.

Each of these factors has several statements which can be analysed to measure the degree to which the factors are fulfilled in a certain context. The statements that are relevant to this study, for each factor, can be seen in table 2.1.

Performance Expectancy
Using the system would improve my job performance.
Using the system would make it easier to do my job.
Use of the system can significantly increase the quality of output of my job.
Effort Expectancy
I would find it easy to get the system to do what I want it to do.
Using the system would take too much time from my normal duties.
I would find the system easy to use.
Social Influence
People who influence my behaviour think I should use the system.
I use the system because of the proportion of coworkers who use the system.
People in my organisation who use the system have more prestige than those who do not.
Facilitating Conditions
I have the resources necessary to use the system.
I have the knowledge necessary to use the system.
A specific person (or group) is available to me for assistance with system difficulties.
I think the system fits well with the way I like to work.

Table 2.1: Statements for each factor in the UTAUT model.

To use this model, these statements can be evaluated by the employees who are or should be using a system in their work. An explanation can then be made as to why a system is or is not being used. In other words, the model can be used to explain behaviour, or inclination towards using a new system. As an important aspect of this study was to investigate whether the socioeconomic status of the children affected the use behaviour of the teachers, the UTAUT model had to be modified by adding questions regarding this matter. The original model also includes age, experience, gender, and voluntariness of use as moderators affecting the factors in the model. These moderators were not included in this study due to the lack of quantitative data. The final modified model used in this study can be seen in figure 2.1.

Since the UTAUT was released it has been widely used in different areas to understand behaviour with regard to the use of technology (Williams et al., 2015). As seen in section 1.4 the framework has also been used in educational research. Some examples of other research that have used the UTAUT are investigation of 3G user behaviour (Wu et al., 2007), understanding the adoption of E-government services (AlAwadhi and Morris, 2008) and individuals' adoption of mobile banking (Zhou et al., 2010). This wide usage has led to several studies that test the model's accuracy, as well as studies that present critique towards the model. Im et al. (2011) statistically tested the UTAUT in a comparative study on MP3-player usage in South Korea and the United States with 550 respondents, by collecting data and analysing how the UTAUT factors affected the end usage. They found that the

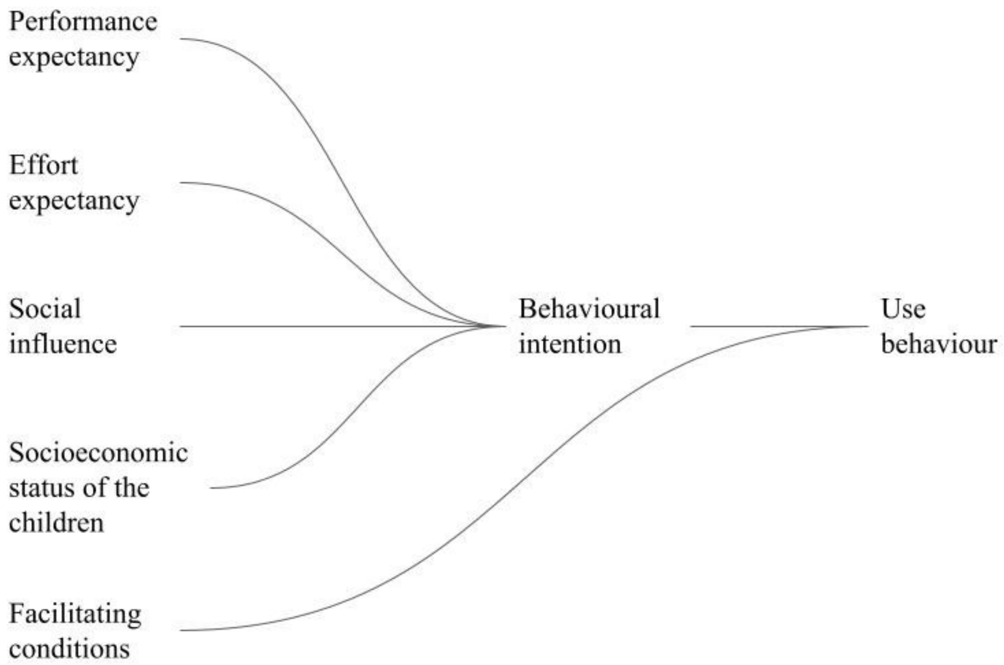

Figure 2.1: Modified version of the UTAUT model.

UTAUT factors significantly affected the end usage and thereby gave confirmation for the theory. A meta-analysis by Khechine et al. (2016), analysed 74 empirical publications that have used the UTAUT. Their analysis also supported that the factors are good estimators for the acceptance of technology. Dwivedi et al. (2019) brings up critique towards UTAUT. One is that parts of the UTAUT may not be applicable in all contexts and that it excludes some factors that can be crucial for user acceptance, especially attitude. They also point out that the moderators used in the UTAUT have been scarcely used and they deem them as irrelevant. Since the UTAUT has been widely used and confirmed to some extent it was deemed as a good choice for this study. The critique was relevant, but it would only make minor changes to the outcome and therefore it was thought unnecessary to change. The moderators were also not used in this study as mentioned above.

2.2 The context

As Sweden was deemed a developed country, where a context where the learners would have little to no access to computers outside school would be difficult to find, it was decided that the study should take place in another country. The authors were then informed of a K-7 school located in South Africa, next to an informal settlement, which houses very poor people. According to the school, they specifically teach underprivileged children, of which a significant portion live in the settlement next to the school, and thus it was decided to do the study at this school. For the purpose of this study, it was decided that observations had to be done in order to explain the context. To achieve this, three areas of the context were observed:

- The living conditions in the informal settlement.
- A general description of the school.
- How the STEM teaching worked at the school.

Through a tour of the informal settlement, it was observed that the settlement was confined to a limited area, shaped like a rectangle, with roads in a grid structure. The roads were not paved and consisted of dirt with rocks. It was also observed that there was no organised waste disposal. The buildings inside the settlement were almost exclusively shacks made from wooden frames and sheet metal. There was no electric grid in the settlement, however, some shacks had small solar panels on the roofs. For cooking, fire was used. There were some shops in the settlement where food could be bought, and some advertised that one could charge their phone for a fee. Along the outlines of the settlement, portable lavatories were placed for the residents to use. There were also some water tanks with fresh water, as the settlement lacked any plumbing. Based on these observations, a conclusion was drawn that the people living there were not likely to have personal computers at home, but were likely to have cell phones.

By being at the school for several weeks, observing classes, conducting lessons, and asking questions, a general description of the school could be made. The school had three main buildings, one for kindergarten, one for grades 1-3, and one for grades 4-7. As the principal thought it best if this study was conducted with grades 4-7, in addition to logistical reasons, the study was conducted with these grades. The children started their day at 07:30 and ended at 14:00 every day. There were seven teachers, each of which had their own classroom where they stayed throughout the day. When the children changed periods, which were 45 minutes long, they also changed classrooms. The classrooms all had seats for 16 children, one whiteboard, and materials related to the teacher who was in the given classroom. One of the classrooms contained nine stationary computers with a monitor, mouse and keyboard, and internet connection. The internet connection was stable but slow. This classroom was the only one with computers.

The STEM teaching at the school mostly consists of the teacher giving instructions on how to do a certain operation, followed by the children working independently in their workbooks, while the teacher provides help where necessary. For the duration of this study, the most common areas of study in mathematics were multiplication tables and fractions.

2.3 Interviews

As the number of teachers at the school was limited, it was decided that all teachers in STEM subjects would be selected as the sample for the study. In table 2.2 the teachers have been given a code, and their respective subjects and grades of teaching have also been listed.

Teacher	Subject	Grades
T1	Natural Science	5-7
T2	Mathematics	6-7
T3	Mathematics	5
T4	Mathematics	4

Table 2.2: Coding that identifies each teacher with the subject and grades they teach.

In order to describe the obstacles to computer integration, data on the teachers' initial inclination towards using ICT in STEM education had to be gathered. To do this, interviews were held, and an interview guide was created. The interviews were based on the statements seen in table 2.1, and were designed according to the guidelines given by Esaiasson et al. (2017). These guidelines are to

- All questions should be short and easy to understand
- Use initial warm-up questions
- Continue with thematic questions
- Use follow-up questions to deepen the answers
- Ask direct questions to get answers to things that have yet to appear
- Finish with an open question if the person would like to add something.

These guidelines were followed to the highest possible extent, and are the theoretical basis for the design of the interviews used in this study.

As the required data for this study was the teachers' opinions and thoughts, and as the UTAUT framework is based on a person's experience with technology, the questions in the interview were designed by taking each statement in table 2.1 and turning it into a descriptive question. As this study focuses on underprivileged children, it was also necessary to gather data regarding the teachers' perception of the children's computer literacy, as this might be an obstacle to computer integration. For this reason, questions were asked about this matter as well. The interview guide with the formulated questions can be seen in appendix A.1.

When creating the interview questions for the second interviews, which were held after the experience of a computer-integrated lesson, it was expected that SI and FC would not be subject to change after the experience with a computer-integrated lesson, and questions about these areas were therefore excluded from these interviews. Questions about PE and EE were still asked, with a focus on comparison to before the experience. A question was also asked about how the children's computer knowledge was affected, in order to see whether or not the teachers thought teaching with computers would have an effect on ICT literacy. The second interview ended with a general question about the teachers' perception of how their own intention to use computers in their teaching had been affected. As these interviews were seen as a continuation of the initial interviews, and as the logistics required very short interviews, some of the guidelines about interviews, such as warm-up questions, were disregarded. The interview guide can be seen in appendix A.2.

2.4 Experience of computer-integrated lesson

In order to answer how an experience of a computer-integrated lesson can affect the teachers' inclination toward using computers in their STEM teaching, two different approaches were taken. Firstly two mathematics lessons using simulations from *PhET: Interactive Simulations* (University of Colorado, n.d.) were created. Secondly, a natural science lesson was planned and conducted by teacher T1. The three mathematics teachers had no previous experience with computers in mathematics therefore it was thought that the most effective way to create the experience was to let them observe a planned lesson. This enabled them to see the effects of integrating computers into mathematics and learn how to do it at the same time. Teacher T1 had recently graduated from university and had some experience using computers in STEM. Therefore it was believed that the best option for the experience of a computer-integrated lesson was to let teacher T1 plan and conduct the lesson themself.

In the sections below, the software PhET, its effects on learning, and why it was chosen will be explained. Thereafter the lesson plans for the mathematics lessons and the natural science lesson are presented.

2.4.1 PhET

For the computer-integrated lessons, a software had to be chosen. It was decided that the selected software had to meet three criteria:

1. Highly visual and interactive
2. User friendly
3. Suitable for grades 4-7

PhET is a freely available software which at the time of writing consists of 163 interactive simulations. It is a project driven by the University of Colorado Boulder and was initiated in 2002 by Nobel laureate Carl Wieman. The simulations have five different subject areas: *Physics*, *Chemistry*, *Math*, *Earth Science*, and *Biology* (University of Colorado, n.d.). This study only used mathematics simulations. The mathematics simulations by themselves stand for 46 simulations, mostly on unique topics. There are simulations that can be applied on every schooling level from first grade up to university. For elementary and middle school applications there are 38 different mathematics simulations which the website recommends (PhET, n.d.).

In contrast to traditional teaching, PhET let the user play around with the mathematical concepts, which according to Hensberry et al. (2018) is beneficial for the learning as well as lesson outcome. PhET also provides a visual representation of mathematical concepts which can help the user understand the topic better. The visual representation PhET provide is likely difficult to achieve without a computer. PhET can therefore provide something to learning that is hard to achieve in a standard classroom environment without computers. Hensberry et al. (2015) found that student attitudes towards the subject content were positively affected by using interactive simulations, such as PhET, as well as an increase in subject learning. It was concluded that PhET met the criteria of being visual and interactive.

Using PhET requires no specific knowledge of how to use it. Compared to some software that requires different levels of user understanding, PhET was deemed an easy alternative for teachers with little experience in using computers in mathematics. There are other software alternatives that could provide similar tools as PhET, for example GeoGebra, however, these often require more computer experience as well as experience with the specific software in order to use effectively, and thus they were not deemed suitable for this study as many of the teachers have little to no experience with this. It was argued that if the threshold for effective use of the selected software was too high, the teachers would expect too much of an effort to learn the software, and it was thus of importance that this study used software with a low threshold. Another aspect that makes PhET easy to use is that there are a lot of already planned lessons on the website. In other words, if a teacher wants to use a certain software but does not have the time to plan an entire lesson the teacher can use one that already exists for that simulation. This is a quality that PhET have, which decreases the effort for usage. It was thus concluded that PhET met the criteria of user friendliness.

As teachers in this study teach grades 4-7, the selected software had to be suitable for these grades. PhET has an abundance of lessons, activities, and simulations available for all grades, including grades 4-7. This abundance makes PhET useful in many areas of teaching, which further adds to the usefulness of the software, in addition to the ease of use. PhET was therefore deemed to be suitable for grades 4-7, and thus met all criteria posed by this study, and was therefore chosen as the software to be used.

2.4.2 Lesson plans

To introduce the mathematics teachers to PhET the following structure was applied. A lesson plan was developed with one of the PhET simulations in focus, which was chosen according to the current study area of the mathematics class. Thereafter the lesson was conducted with each teacher's respective mathematics class. The teachers assumed the role of an observer during the lessons. The purpose was that they could learn how it works and can be used, but also to let them see the effect it can have on the children. The hope was that their PE and EE would be positively affected by this. In other words, the hypothesis was that if they got to see the benefit of and how effortless computer usage in mathematics can be then they would be more inclined to actually use computers.

The computer-integrated lessons were conducted during school time and covered topics relevant to the curriculum. This meant that the teachers did not have to put extra time outside of school to be introduced individually to PhET. Neither did they have to give up valuable lesson time to do something outside the curriculum. However, the lessons' structures were different from what the teachers would normally do, which could have affected how much the teachers felt that they were wasting lesson time. This structure also meant that the teachers could see how the learners reacted to the computers and what the learning outcome could be, as the teachers simultaneously learned how to use PhET.

After observing the classes and studying the curriculum it was decided that two different lessons had to be planned. One lesson used the *Arithmetic* simulation and was mainly aimed at grade four. The other one used the *Fraction Matcher* simulation and was mainly aimed at grades five, six and seven. Both of the lessons had a time frame of 45 minutes.

The Arithmetic simulation has three different themes: *Multiplication*, *Factors* and *Division*. This lesson focused on the Factors theme. A screenshot of the simulation can be seen in figure 2.2. The main task in this simulation is to fill up the multiplication tables. There are three different levels in each theme and the difference is the size of the multiplication table. As can be seen in figure 2.2 the first level has a 6x6 multiplication table. The purpose of the simulation is to practice the multiplication tables, and to see that the shaded rectangles, seen as purple in figure 2.2, can be used to calculate the products. This provides a visual representation of multiplication that can be of use to the learners. When the learners took part in the lesson they received a sheet, see appendix A.3, which guided them through the simulation and helped them find it. The lesson had the following events which the learners had to complete themselves:

1. Find the simulation.
2. Try the first level in the factors theme.
3. Answer questions that helped them understand the concept of factoring through the simulation.
4. Play the other levels and record the time and scores.

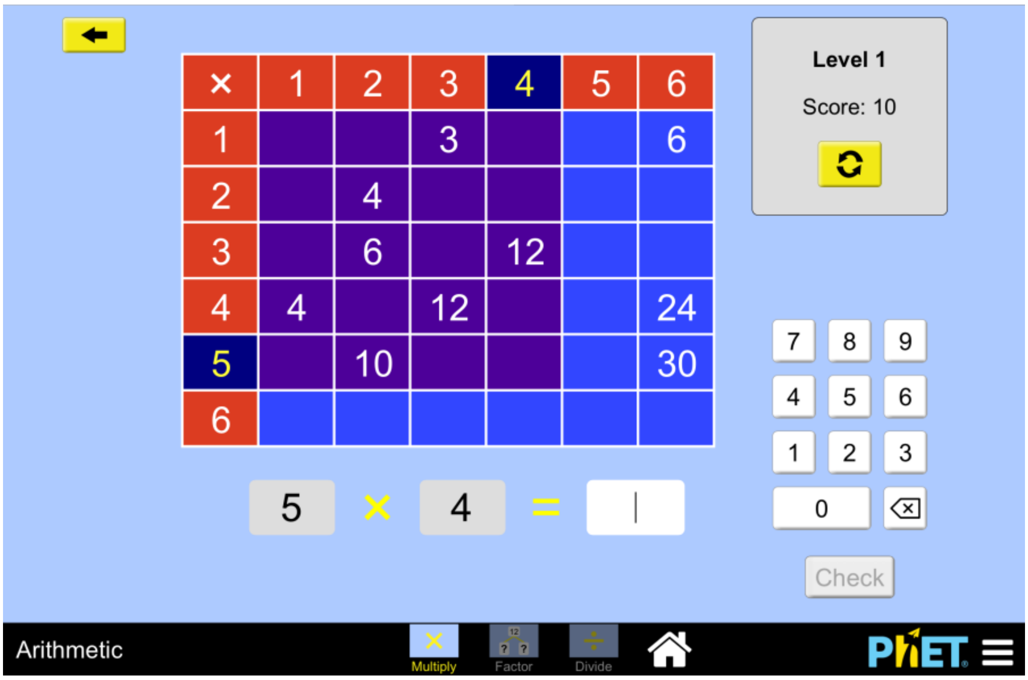

Figure 2.2: Screenshot of the Arithmetic simulation.
Comment. From *Arithmetic* [illustration], by PhET Interactive Simulations, n.d., PhET (https://phet.colorado.edu/en/simulations/arithmetic). CC-BY-4.0

The Fraction Matcher simulation has two different themes: *Fractions* and *Mixed numbers*. This lesson used the Fractions theme. In the Fractions theme there were eight different levels of difficulty. In figure 2.3 a screenshot of the simulation can be seen. The task is to choose the fractions and figures at the bottom of the frame and match them. When they are matched correctly the player gets points. If they are incorrectly matched there will be an inequality sign where the equality sign is in figure 2.3. The bars in the middle of the frame will also be put according to the sizes of the fractions in the number line. The purpose of the simulation is to practise fractions and how one fraction can be represented in different ways. Similarly to the Arithmetic lesson, the learners received a sheet with instructions to follow, which can be seen in appendix A.4. The lesson had the following events which the learners had to complete themselves:

1. Find the simulation.
2. Try the first level in the fractions theme.
3. Answer questions that helped them understand the hints in the simulation.
4. Play the other levels and record the time and scores.

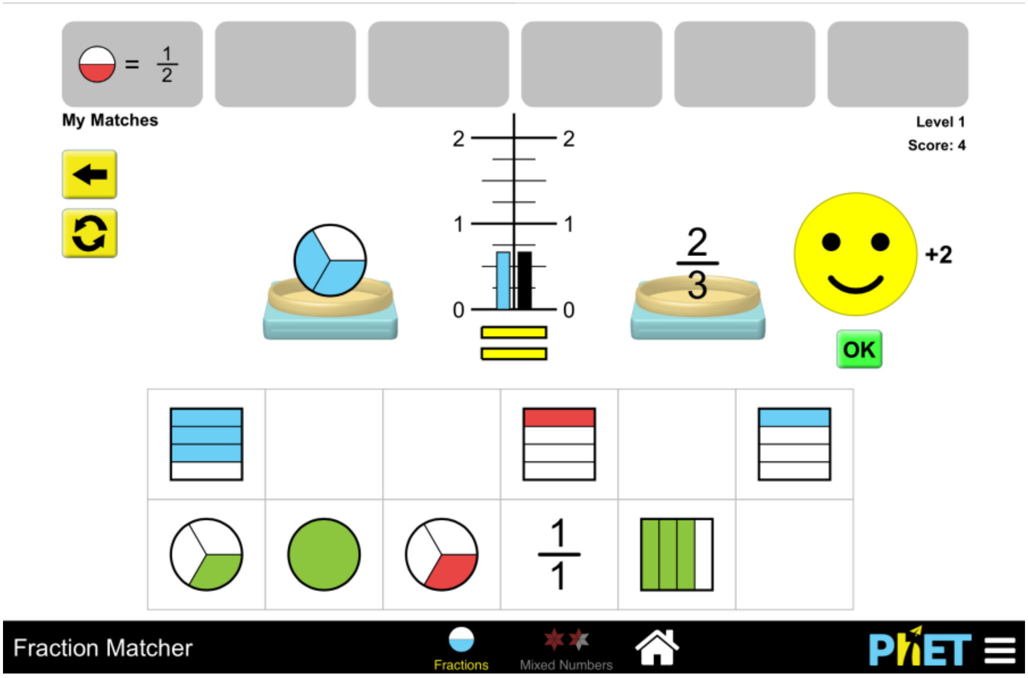

Figure 2.3: Screenshot the Fraction Matcher simulation.
Comment. From *Fraction Matcher* [illustration], by PhET Interactive Simulations, n.d., PhET (`https://phet.colorado.edu/en/simulations/fraction-matcher`). CC-BY-4.0

The lesson T1 planned was a natural science class for grade six. The lesson content was food chains and food webs. The structure was that the learners had to do an interactive activity on *PBS: Learning Media*'s website (PBS Learning Media, n.d.). In the activity, the learners got to build food chains and food webs. When a food chain had been built correctly a video was shown where one of the organisms ate the one below it in the food chain.

2.5 Data analysis

In order to answer the research questions the data had to be analysed. The procedure of the analysis was to transcribe the interviews, summarise the interview answers, code the answers, and map the codes by applying the mapping method.

Following the transcription, a summary of the answers for each interview question was created using the template in table 2.3. The purpose of the summary was to get an overview of the interview answers.

Teacher/Question	*Each respective interview question*
T1	*Summary of T1's answer*
T2	*Summary of T2's answer*
T3	*Summary of T3's answer*
T4	*Summary of T4's answer*

Table 2.3: Template for interview summary.

As mentioned in the introduction of chapter 2 the mapping method was suggested by Esaiasson et al. (2017) to be the best method for data analysis in this study. The method works by taking the phenomenon in question, and based on the data, dividing it into categories, which in turn can be divided further into subcategories, and so on. Finally, defining aspects of each subcategory should be stated. Motivation for each category, subcategory, and defining aspects should be strengthened by the data. In figure 2.4 a flowchart of the mapping method can be seen. As the aim was to describe obstacles, and the UTAUT framework suggests that a person's perceptions are what determines behaviour, and therefore obstacles, the teachers' perceptions of computer usage were chosen as a phenomenon to be mapped. To determine how an experience with a computer-integrated lesson might affect teachers' intentions to use computers, the teachers' change in intention was chosen as a secondary phenomenon to be mapped.

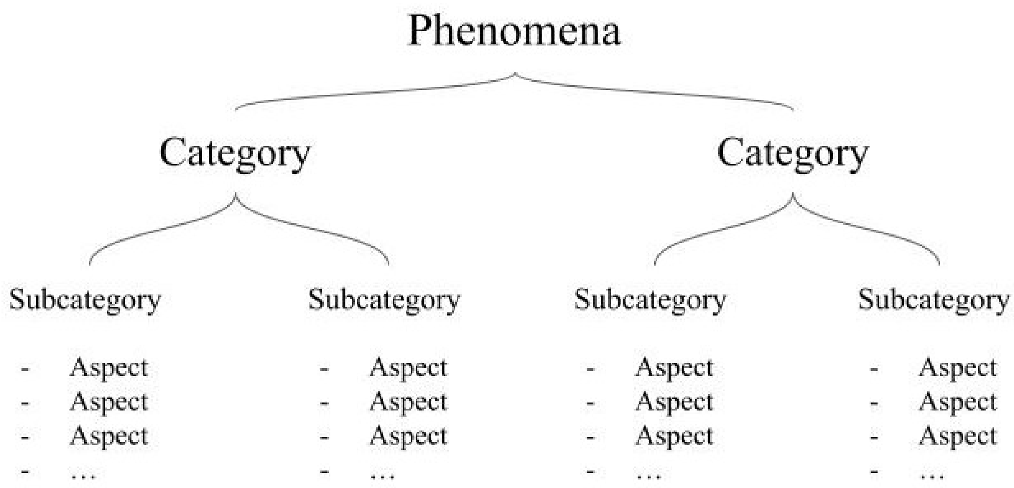

Figure 2.4: Flowchart of the mapping method.

In order to effectively map the data, a qualitative data analysis software called Nvivo Lumivero (n.d.) was used. In Nvivo quotes were coded according to the themes they were describing. If the codes were describing the same overall aspects they were put in a folder which would then be the defining aspects as in the mapping method. One example of this was the defining aspect *Computers increase lesson quality*. In this aspect, five different codes were found in the interviews. One of them was *Computers engage the learners*. Nine quotes were categorised into this code. Two examples were:

> '[...] for getting more kids attention even kids that thought they didn't like math might start liking it because of the computers.' - T3
>
> 'No I think it [using computers] will be an advantage to everyone. And to me as a teacher, just to get the children involved in something and get them excited, yeah it's a great thing. And then the reward of when you see their progress.' - T4

When all interviews had been coded the categories and subcategories of the phenomena to be mapped were created. The final results of the data analysis were then represented as a flowchart based on the flowchart seen in figure 2.4.

3

Results

In the following chapter, the results from both parts of the study will be presented. The first part is the interviews which investigated the teachers' perception of computer usage in their STEM education. The second part is the interviews held after the computer-integrated lessons which the teachers observed. All interviews were analysed with the mapping method in accordance with the process described in section 2.5. The mapping of the interviews is presented for both parts and is motivated by representative quotes.

3.1 Obstacles to computer usage

Figure 3.1 shows the mapping of the interviews done before the lessons in accordance with the mapping method presented in section 2.5. The first subcategories are the same as in the UTAUT framework, as seen in section 2.1. There was also an addition of the category SES, which aimed to see how the teachers' perception of using computers was affected by the children's SES. Furthermore, all of the categories were sub-categorized into *Positive* and *Negative/neutral*, as the teachers' answers either indicated a positive attitude, or a negative/neutral attitude. The defining aspects of these categories were then listed. The motivations for this categorisation are presented below, with representative quotes from each interview for every category.

3.1.1 Performance expectancy

In the interviews, three themes were identified regarding PE. These were subject learning, lesson quality, and difficulty of planning. The teachers' perceptions were in general positive, with varying amounts of scepticism.

One positive view of the PE was that computers could increase subject learning by adding visual representations to the lesson and by providing more in depth explanations to the learners.

> 'Well I think it would be better for them because you know visually, when you show something, the learning ability is much more and quicker than when you're sitting in a classroom.' - T4

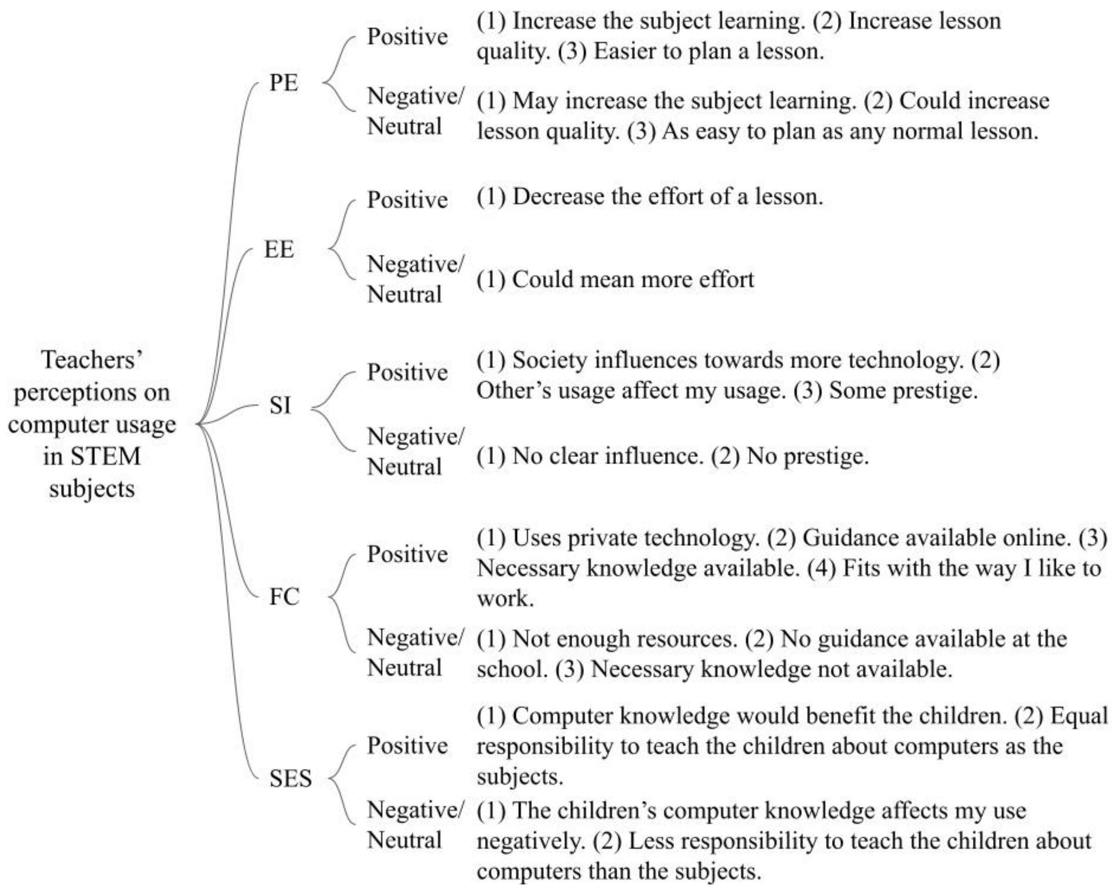

Figure 3.1: Results from initial interviews using the mapping method.

Another positive aspect was student engagement. One teacher expressed that computers might increase the children's motivation and excitement towards the subject, which would increase lesson quality.

> '[...] here's the thing I think can be very positive. I think the children must enjoy something, right? And one must be very careful, especially in a subject like maths, which can scare a lot of children. You know when they enter the maths class *gasps*, they say "I can't do this", so computers can also bring in the fun element, because the moment a child is positive about the subject, he or she is starting to do better in that subject. So that can be an extremely positive thing, because especially for these children they love to play on the computers. So that's a fun way of doing it.' - T2

There were mentions of computers improving a lesson by providing special education for children who might need it.

> 'You know using a book and writing the whole time doesn't work for everyone. Like I don't know if I told you guys about that boy that's in grade six now that was with me last year. He could answer every single

> question if I did it on the board. He would tell me exactly what to do, but the moment he has to write it he get such low marks and I know that he can get 90 % and up. Because he knows it, he just needs somebody to write it down for him. I mean what if computers was his answer? So I would definitely be open to that.' - T3

There was however some scepticism toward how the lesson quality would be affected. One negative aspect was that there is no time for computers in the curriculum. Therefore parts of the curriculum might have to be discarded if a teacher decides to have computer-integrated lessons. The following was said about this:

> 'And as I said, there is a huge problem that you have a curriculum that you need to finish. These children struggle to go through the curriculum as it is, because they come to a point where they don't understand the maths, and then you must stop and first explain it again.' -T2

Another negative aspect of computers was that they might be an obstacle when building relationships with the students and teaching them about values. One teacher said:

> 'I just don't think that [teaching with computers] should be the only way, because they need connection with someone. And it's more than just teaching, it's values that's being put in their lives, that you won't get with the computer. So I'm not against teaching with computers, but in a school like this, well actually, with any child, it's not the only way that we must do it. [...] I think it can be positive, but within boundaries.' - T2

This is however not completely negative as it indicates that computers, if used moderately, could be good for lesson quality. This view was seen in other answers as well.

> '[...] but what everyone saw is that to just use computers is not the solution for children. They must have someone that's teaching them as well. So I again think it's a combination.' - T2

When it comes to planning lessons there was a worry that the discipline might become more of a problem. One teacher explained it like this:

> 'So, when you think of the discipline aspect of it, while planning your lesson. So, I think in a child's brain, when they think computer they think game, they think fun, they don't think learning, you know, so that is a complication that can come from if you try to incorporate technology with it.' - T1

However, the same teacher expressed that the difficulty would be different, but not an increase:

> 'So I don't think it increases difficulty I just think it's a new challenge, a different challenge' - T1

which means that the teacher does not necessarily view computer lessons as harder to plan even if the discipline might be a problem.

The general thoughts on PE were deemed positive, but with some scepticism. Worries were mostly moderate and included time, discipline, and relationships with the teachers. There were no thoughts that directly indicated that computers would decrease learning, quality, or planning effort.

3.1.2 Effort expectancy

For effort expectancy two major themes were identified: that computers decrease the effort of conducting lessons, and that computer usage could mean more effort for the teachers. One way that the teachers saw that the effort could be decreased was that the computer takes away some of the responsibility of teaching that the teacher previously had.

> 'I would feel that it decreases the effort for the teacher. Because the learners already have the content there, you basically just need to be an observer and make sure that they actually get the specific information they need' - T1

The fact that using computers could take away the need for printing papers was also mentioned as something that lowers the effort. This was described as something that makes it easier to be spontaneous and come up with new ideas:

> Well it would be easier if you decide, like lets say today I wanna do something new that I didn't plan for. It would be quite easy to implement it, right? Because then you didn't have to go downstairs and make photocopies and everything. - T3

The main effort brought up was the logistics and availability of the computer room at the school. The teachers mentioned that it takes a lot of planning to get a spot in the computer room.

> 'Well first of all it would have to be easily accessible. That at this moment is a problem because I have to schedule times to go there. Which would have to be times that T2 has off. So in that it would be difficult.' - T3

The results regarding EE were deemed mostly positive, as the main concerns did not directly regard the effort of a lesson, but the effort the surrounding conditions gave rise to.

3.1.3 Social influence

In the category of social influence, the influence of society was mentioned, as well as the influence of other teachers. The teachers expressed that society is going towards more usage of technology and that this will be an important skill for the learners in the future.

> 'Yes, well in today's society technology, it's flourishing, that is the path we are moving into so you are more influenced to use it [computers] because that is what the whole world and the society expect of you. I mean a child need to be able to use and be comfortable to use the technology' - T1

It was however also mentioned that there was no particular influence at the school toward using computers or not. One teacher said:

> 'At the moment there is no pressure for us, nobody tells us that we must do it.' - T3

The teachers brought up that they would be more likely to incorporate computers if someone else used them.

> 'If I saw other people using it, yes, definitely, because you can learn from them, how to incorporate it, so yeah, that would influence me.' - T1

Another teacher did however point out that if computers were to be used in the future it would have to be a collective decision since that is how they generally work in the school.

> 'I think in a school like our school we will make the decision in the group, so we can encourage each other, so we can help each other. So I don't think there will be one that's using it and others that are not using it.' - T2

When it comes to the prestige of using computers it was mostly said that society in general favors computers. Not necessarily that the school or the specific teacher would gain any social credit if they were to use computers. One teacher did however say the following about the prestige of using computers:

> 'To me, no [prestige]. I love teachers that can be creative, and that can be excited about their subject and that can bring joy through difficult things, so no, not to me.' - T2

Even though the teacher specifically said that there was no prestige in computers the description of a 'creative teacher' could be interpreted as being prestigious.

The general social influence was deemed to be mostly neutral or slightly positive, whereas society was the biggest source of positive influence.

3.1.4 Facilitating conditions

The views on the FC varied. The teachers were unanimous regarding the availability of resources, and on what guidance was available. They did however express different thoughts on whether they had the necessary knowledge.

The resources at the school were deemed as lacking by the teachers. It was clearly stated in the following quote:

> 'No, we don't have the necessary resources, we don't have enough, which makes it difficult.' - T2

This also relates to the effort expectancy where the biggest problem stated was that it is difficult to access the computers. This was stated by one teacher:

> Yes, we have computers and stuff but access to them on an every single day basis is very hard. So, I don't think the resources that we have now are enough for them to actually learn the skills that they need with the technology. - T1

It was further said that the available computers were not enough for every child to work on their own computer.

> 'Even there [computer room] it's not enough computers for everyone.' - T2.

One teacher solved this by bringing private equipment.

> 'At this moment, no. The only resources that I bring in with the technology are things that I have from home so basically I only have a television and my laptop so I can show them something on the television.' - T1

The teachers felt that there was no guidance available to them in the school on how to use the computers, however, they also mention that guidance is abundant online.

> 'In the school, personally I would have to say no. No one has come and said "okay, this is how you need to incorporate it, this is how you use it, this might be the problem of the lesson", so not in the school physically now, but because we are not so technology inclined, I think that's why I don't have as much guidance from the school.' - T1

> 'No but I think there's a lot of information on the internet.' - T2

> 'There's multiple places where you can find guidance on how you can

> incorporate it. And I mean when I plan my lessons I do my online research to see how I can interpret it.' - T1.

Regarding necessary knowledge, there were different views. Some experienced that they knew enough, while some did not. The lack of knowledge was however not described as an obstacle.

> 'I guess not. Because I don't know specific programs or websites that you can use. But I guess it is not difficult too.' - T3

> 'In university we have a certain subject teaching you how to incorporate technology into your classroom, so it is a basic knowledge that we as teachers need to know because that is the world that we live in. So I do feel that I have the knowledge to be able to incorporate technology in my classes.' - T1

Time was also mentioned as a resource that was problematic.

> 'My worry is time, because you know, as I said, you've got a certain amount, or huge amount, of work you need to do in a small amount of time that you must finish, so you can't waste a lot of time playing, although these things are good for the children.' - T2

In general, the teachers felt that using computers fit with the way they like to teach. It was explained like this:

> 'Well, when I look at my teaching style, I love an interactive teaching style, I love the kids to have their opinions, to be incorporated into the lesson, so I think using technology, they are the whole time busy.' - T1

> 'Yeah I think it can definitely fit. Because I'm open to some new ideas because we see that the current things don't work for everyone. You know using a book and writing the whole time doesn't work for everyone.' - T3

The general view of FC was negative. It was described that resources were not enough, that guidance was scarce, and that time was an issue. Using computers in maths was however described as something that would fit with how the teachers like to work.

3.1.5 Socioeconomic status

The general themes regarding SES were whether the SES of the children affected the teachers' usage of computers in their subjects, the degree to which the teachers felt responsible to teach the children about computers, and to what extent computer knowledge would benefit the children.

The SES of the children mostly affected the teachers' usage negatively.

> 'The problem it can cause is that you need to spend extra time teaching them generally how to use [a computer] before you can actually incorporate the actual lesson, the content you need to do with them.' - T1

> 'I guess that's why we didn't use them until now, we thought maybe they won't know how [to use computers].' - T3

The degree to which the teachers felt responsible for teaching the children about computers varied. Some expressed a feeling of responsibility to the same extent as with teaching the subjects, while others felt less responsibility.

> 'As much of an extent that I feel responsible for teaching them the learning content. Like I said in the world we live in today they need these skills, they need to be able to do that because that is where we are going to.' - T1

> 'At the moment there is no pressure for us, nobody tells us that we must do it. But again if you want the best for the kids then I guess you'll have to put some pressure on yourself to start using [computers in maths]. If you wanna be a good teacher then you gonna have to look into it.' - T3

> 'My biggest priority is that they will understand the maths but if I can use the computer to help me with that I'm not negative about it. But as I say it takes a lot of energy just for me to get them to understand the maths. But I also probably have a huge responsibility to use technology because that is what's going on in the world.' - T2

Regarding whether improved computer knowledge would benefit the children, the teachers were unanimous. There were expressions both regarding benefits to learning other subject knowledge, as well as it being beneficial in life.

> 'I think it would benefit them to an extent that it would be so much easier and so much more engaging for them, if they knew how to actually use these computers.' - T1

> 'It would definitely benefit them in high school, because I think at high schools, especially the good ones, they will be behind if they don't know how to use it well. [...] Yes definitely, even if they go to high school and university and even just to find a job maybe if they don't go to university. I mean we all know that if you want to apply for a job you have to have the basic skills for word or excel at least.' - T3

> 'Well the world is using technology so we understand the importance of technology and that's why we want to introduce them as much as possi-

ble to technology.' - T2

'It will definitely benefit them, yes. In life, in school, in every way. I think their minds and their decision making will, you know they will be a different outlook on everything.' - T4

To summarize, the results regarding SES were mixed, but generally positive. The teachers thought that the children's computer knowledge would affect the teaching to the degree that they avoided computers in their subjects partly because of this. They felt responsible to some degree to teach the children about computers, and they thought it would benefit the children if they were better at using computers.

3.2 Experience of computer-integrated lesson

Similar to section 3.1, the answers to the second interviews were analysed using the mapping method, and the results of this can be seen in figure 3.2. One change, however, is that SI, FC, and SES were excluded from these results. This was due to the fact that neither SI, FC, or SES were deemed possible to be affected by the computer-integrated lessons used in this study. The hypothesis was that only PE and EE from the UTAUT framework would be affected. It was also of interest to see whether the teachers perceived the use of computers as beneficial for the children, and if they experienced any conscious change in intention to use computers in their education. As a result of this, the categories *Change in intention*, and *Computer knowledge* were added. The motivation for the categorisation will be presented below with representative quotes from the interviews.

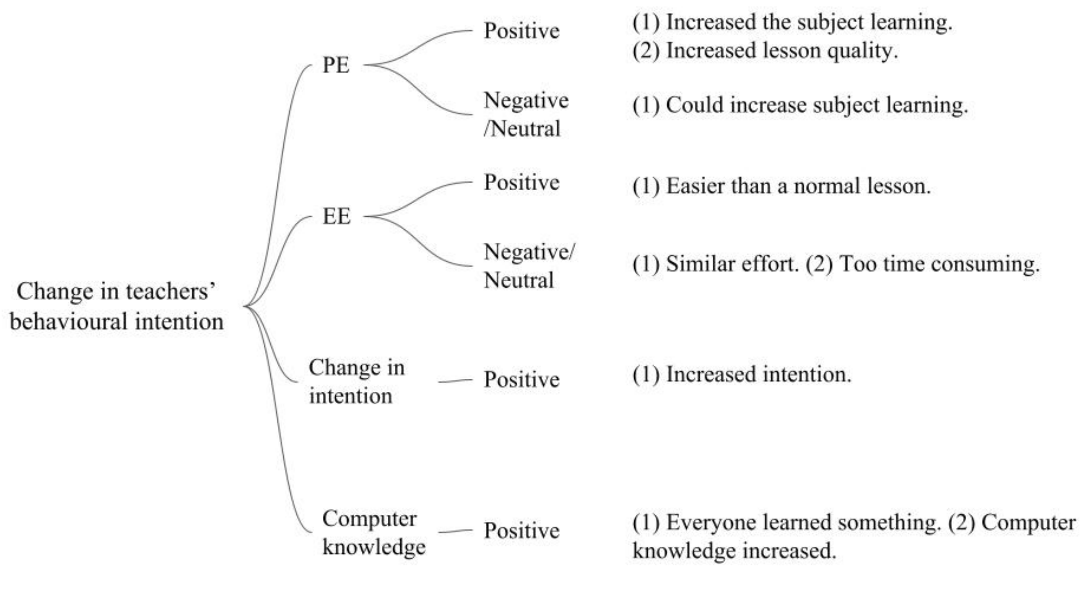

Figure 3.2: Results of the second interviews using the mapping method.

3.2.1 Performance expectancy

There were several positive attitudes with regard to PE. The teachers expressed that using the computers increased the subject learning more than a normal lesson would:

> 'I was so pleasantly surprised by, I think it had way more impact than a normal lesson. It felt like even the kids that normally really struggle with maths, even them, it's like something just clicked, so they suddenly understood. Especially the fractions, the factors we did, I was pleasantly surprised. I really hope that this will be a part of the future.' - T3

> 'Well, with this one they learned extra information that they normally wouldn't be learning, for example the different aspects of each animal while they were completing their activity so I think that's what the main big difference is, the concept was broadened. So the learning is broadened with the use of technology.' - T1

There were also thoughts that using computers increased enjoyment and excitement, which was interpreted as positive:

> 'It's much more exciting and I think the children enjoy it very much. Especially when they have to figure out the answer, there's different ways to get to the answer, that's quite exciting.' - T4

Some answers were more hesitant towards a positive PE, however, this teacher argues that the PE can be increased if the usage is done correctly:

> 'Look, they like it, they enjoy it. The one problem we have is time. Our curriculum is just so full that even in your normal schools, they struggle to get through it. But to bring things in like this is very positive, because lots of children find maths, they're scared for it, they're negative about it, because they struggle with it. So to do these fun things, these games is wonderful so maybe we must think, you know once a month or once a term or whatever to make a fun day with maths and how you play games, do maths games.' - T2

> 'Let's take the one with the fractions because I really love that one. I could see how all the children are doing everything, but with the fractions, that you do the teaching, and then they go to the computer. And then they do the exercise. So the teacher must be very aware, she must play the game first obviously. And then she says right I've done this now, I've showed you everything, and now you're going to work against time. Because then they know what they're supposed to do. Even after they've done one or two exercises in their workbooks, and then they go to the computer' - T2

Based on these answers, the general change in PE was deemed positive, or positive with conditions.

3.2.2 Effort expectancy

Similar to PE, the change in EE was mostly positive, with some hesitancy. There were expressions of computer-integrated lessons being easier:

> 'I mean this was effortless, we decided this morning and we did it so I guess the effort will be a lot less, as long as you know where the websites are and things and what to click, then it was fine. But he [William] showed me and it was really easy.' - T3

> 'Yes [it would be easier]. And for them to get it visually and to try to learn the technology and everything, everything is new to them, but I think they're more excited about what they've accomplished today than any other day.' - T4

Some teachers expressed that a lesson with computers would mean neither more nor less effort than a normal lesson:

> 'I don't think there's any more effort for preparing a lesson like this. I think it's the same amount I would have with a normal lesson. The only effort I think would have been as you could see at the end they went on to Youtube, that's the only effort you need to be prepared for, but planning wise, content wise, for me it's exactly the same.' - T1

One teacher once again expressed that it could be useful, but that certain conditions had to be met:

> 'Look, they like it, they enjoy it. The one problem we have is time. Our curriculum is just so full that even in your normal schools, they struggle to get through it.' - T2

As with PE, the change in EE was deemed mostly positive, or positive with conditions.

3.2.3 Change in intention

Regarding the teachers' own perceptions of their change in intention the results were solely positive.

> 'I would say my interest in it was broadened more because like I said now they have a broadened content learning so for me it increases my wanting to use computers on an everyday basis. I think I want to do it

even more.' - T1

'I think positive, because I could see they joy of the children, and I could also see how they're benefiting. Even the ones that's really struggling with maths, so I think very positive.' - T2

'I wish I could do [computers in maths] everyday with them, yes. They would be so, looking forward to the maths class, so I wish really we could do it everyday. Even if we could do it two times a week it will be fantastic.' - T4

'Greatly, it's been affected greatly. So I will definitely, I don't think I will attempt to do maths with kids anymore without computers, that would be stupid. We saw the results yesterday, and it was so easy to get results now. I couldn't believe how kids suddenly understood the fractions. Before I had to cut apples and draw pictures like a million times and some of them still don't understand, but with the computers it was like almost instantly, so maybe their brains are just wired for screens? So yeah, I will definitely use it in the future. ' - T3

The results strongly indicate that the teachers perceive their own intention to use computers in maths greatly affected in a positive way.

3.2.4 Computer knowledge

One important aspect of this study was that the use of computers in maths would, to some degree, increase the computer knowledge of the children. As the results from the first interviews show, the teachers found it positive if this knowledge was increased. It was therefore asked whether the teachers thought that the children increased their computer knowledge during the lessons. The results show that the teachers thought that either some or all of the children learned something.

'It was a smaller number of them that struggled. I thought that they actually, they had to understand the game, and then they were going.' - T2

'Well, I could see that some of them were not familiar with the mouse which we said made sense since normally they just use a screen, right? Like cell phone screens, that's the only thing they kind of know or even laptops don't have a mouse. But, they didn't struggle at all, when I showed them you have to push the left button, it was, from there on, smooth sailing.' - T3

'You know, because they don't have lots of, most of them don't, on a daily basis use computers so it's very new. But you can see they're so inquisitive they want to learn more. So it's very stimulating.' - T4

The teachers thought that some of the children struggled, while some already knew enough about computers. They point out that the ones who struggled learned quickly. The perception that computer knowledge was positively affected was unanimous. The results were therefore deemed positive.

4 Discussion

In this chapter, the methodology of the study and its effects on the results will be discussed. The results from the interviews will be summarized and discussed. Finally, the results from the experience of a computer-integrated lesson will be summarized and discussed. Conclusions will then be drawn based on these discussions.

4.1 Methodology

The results of this study are qualitative. The conclusions drawn in section 4.2 and 4.3 might therefore not be true in general. The context of this study is also unique, as it was conducted at one school only. This school had one way of offering computers to the learners, other schools might have different solutions to this, which might make FC less of a problem. In another setting there could be different problems such as a disbelief in the performance computers have in teaching which could decrease the chance that they will use computers. Some schools might not even have computers available to the learners. The results have to be read with this in mind. The results might also indicate some general obstacles, but they could also be somewhat specific to the school where the study was conducted. Similarly, the effect of the computer-integrated lesson experience might vary depending on the context. To draw more general conclusions, these research questions would have to be tested quantitatively.

One flaw with the research method is that it was based on self-evaluation by the teachers. As the UTAUT model is based on self-perception, it could be argued that self-evaluation was a necessary method, however, with regards to the extent these perceptions correspond to reality, self-evaluation has low validity (Mabe and West, 1982). This issue became apparent in the interview question regarding effort expectancy. The teachers were asked the same question, however, each teacher spoke of different aspects of why the effort was perceived in a certain way. This also indicates that the question was too complex. The answers seem to be based on each teacher's own perception of what effort is, which likely lowers the validity of the results.

Some of the questions in the interviews could be classified as leading questions. The questions regarding the facilitating conditions were formulated as yes or no questions depending on whether the teacher felt like he or she had enough resources, instead of being asked to describe the available resources. This could affect the results regarding FC to be more positively inclined (Loftus, 1975).

For the experience of a computer-integrated STEM lesson, PhET was chosen as the software to be used. PhET was chosen as it met all criteria posed by the circumstances of the study, however, it is likely not the only software that meets these criteria. This selection could affect the outcomes of the experience of a computer-integrated lesson, and a comparison with different software would be required to draw any conclusions regarding this.

The effect the interviewers could have had on the teachers should also be mentioned. As the authors of this study spent a significant amount of time in the school, they got to know the teachers on a professional level. The authors were also open about the purpose of their visit, which included a positive attitude towards using computers in STEM. This could have had an effect on the teachers' perceptions about using computers in STEM, which would affect the results of the interviews.

All aspects described in this section could have an effect on the results, and should be considered when interpreting the results, when drawing conclusions, and when using the results in a real-world application.

4.2 Obstacles to computer usage

As mentioned in section 3.1.1 the teachers' general perception was that computers could perform well in the classroom. Most of the scepticism toward using computers came from teacher T2. The scepticism consisted of a belief that computers could impair the relationships between teachers and students and that parts of the curriculum would have to be discarded to leave space for computer-integrated lessons. These worries could be legitimate, however, they seemed to be based on a perception that computers would replace the teacher as source of teaching, which does not have to be the case. One positive aspect which T2 addressed was the engagement computers could bring, and that the computers could positively affect the feelings learners associate with mathematics. It appeared as if T2 did not see clear learning benefits from computer-integrated teaching, but rather that it would only be something fun for the students. The other teachers were mostly positive about the performance and expressed few negative aspects. Teacher T1 was an exception who said that discipline could become a bigger problem when planning a lesson compared to a normal lesson. T1 did however state that other aspects of the lesson would be easier and that it would be of similar difficulty in total. To conclude, the results indicate that, in accordance with Saal et al. (2020), performance expectancy was in general high, and was deemed not to be a clear obstacle.

Drawing from the answers on EE in section 3.1.2 it was concluded in section 4.1 that the interview questions probably were too unspecific and it seemed as if the teachers interpreted effort in several different ways. Most of them answered with a 'no it's going to be easy', not clarifying why and not really showing that they had reflected on the problems that might occur. The answers were however mostly positive. The only effort that was present in the answers was the need of scheduling computer lessons, which appeared to be quite an effort. Even if the teachers might not have reflected on the efforts computers might bring them, the UTAUT framework claims that it does not matter, as the fact that they see it as effortless means that they are more likely to accept and use computers. Even though the validity of the results regarding EE was compromised, a conclusion was made that EE was not a major obstacle, as the perception of effort was the main aspect of this category. It should however be noted that Saal et al. (2020) did a similar study, in which the teachers thought computer usage was hard.

In the category of SI, the results were mostly neutral. The teachers expressed no pressure neither towards nor against the use of computers. There was a tendency to mention a societal development toward more technology and that it is good to use computers because of that. This was however a rather abstract and unspecific influence. If, for example, the government provided some sort of incentive for the schools to use computers more it would probably have a larger influence. No teacher believed that it was prestigious to use computers in education. It further appeared as if it would affect the teachers if someone else started using computers. They mostly said that in such a situation, they could learn from the other teachers. It could also be an indication that none of the teachers would want to be the first person to introduce computers. To conclude there seemed to be neither influence toward nor away from computers. SI was therefore not deemed as an obstacle even if a more positive SI probably would increase the likelihood of the integration of computers.

Regarding FC it was quite clear, based on the answers in section 3.1.4, that the teachers experienced a lack of resources. There was one computer room at the school which almost always was occupied by T2. This configuration made it hard for teachers to access computers, and could explain why they experienced a lack of resources. In the computer room, the number of computers was not enough for one class, which some teachers saw as a problem. There was no guidance at the school on how to use the computers, although the teachers did not see this as a problem since they believed that they could find the necessary information on the Internet. It could however be argued that a guide would have more influence than only relying on the Internet. The teachers also viewed their own knowledge about how to use computers in lessons quite differently. Teacher T1 received some experience in university, while the others had no specific knowledge, but did not see that as a big problem. The teachers' opinions about their own abilities are difficult to evaluate, as their lack of experience likely means that they do not know the difficulty of learning how to use computers in their subjects. This case is however the same as with effort expectancy. If the teachers do not view it as an obstacle it will not affect the likeliness of them using computers, according to the UTAUT framework. In conclusion, FC seems to be a problem at the school. The teachers did not perceive the resources as enough, neither physical resources nor knowledge. FC was therefore deemed as a main obstacle to incorporating computers in STEM teaching.

In section 3.1.5 it seemed as if the SES of the children could affect the teachers' usage of computers since they expected the children to have low computer knowledge. This could be tied to both PE and EE. Low computer literacy amongst the children could be perceived by the teachers as something that could decrease the performance in a lesson, or increase the effort of conducting a lesson. The feeling of responsibility to teach computer skills varied. One teacher said that it was on the same level as subject knowledge, and one said that subject knowledge was more important. All of the teachers however mentioned that the world is developing towards more technology usage, and that the children therefore have to be taught how to use computers. Furthermore, the results indicate that the teachers perceived computer knowledge as beneficial for the children. The benefits they expressed were in later schooling, in life, in subject learning, and with finding work. Even though the teachers felt it was beneficial for the children to learn how to use computers, this feeling was not enough to induce computer usage. Combined with the perception that the children's computer literacy was low, it was concluded that the computer literacy of the children might be an obstacle to computer integration.

It would seem as FC was the main obstacle for teachers to incorporate computers in their teaching, however, with some planning, it was possible to arrange computer-integrated lessons. While the current arrangement with the computers in one classroom might not be optimal, there are ways to use them in the lessons. This indicates that while both PE and EE to some degree seemed positive, they did not affect the teachers enough to arrange computer-integrated lessons themselves. It could also indicate that the influence teacher T2, whose classroom contains the computers, has on the other teachers might be of more importance than the results show. If T2 was determined to make computer-integrated lessons possible, it could probably be done. Despite this, the results indicate that the teachers perceived the FC as too difficult, even if it technically could be enough, and thus this study still concludes that FC was the main obstacle. Another possible conclusion is that the actual obstacle is the product of PE, EE, and FC, where in this case, PE and EE are not positive enough for the low FC to be enough. The conclusion could therefore be that the FC are too low to match the current PE and EE, and is, therefore, the main obstacle.

Although the teachers have a positive perception of using computers, most of them had never used computers in STEM. This means that they are unlikely to know the full effort of using computers, the possible performance, or how hard it would be for them to acquire the needed knowledge. However, as the UTAUT focus on the teachers' perceptions, their experience with computers does not matter much if it does not affect their perceptions. The teachers' actual experience might however be of more importance than the results suggest. Reviewing the interview data it appears as if the resources are the main obstacle, but as mentioned above it is fully possible to arrange computer-integrated lessons. According to the UTAUT framework, with such a positive perception of computer usage as the teachers express, it would be likely that they would use computers if it was possible. However, that is not the case, which entails that resources are unlikely to be the only obstacle. A possible conclusion is that the teachers' lack of experience leads to an unconscious perception of PE and EE which might be lower than what was expressed. A positive experience with a computer-integrated lesson might therefore have a larger effect than previously expected.

To conclude, it can be said that the general PE of using computers were high. One teacher was sceptical, but still expressed a somewhat positive view. The EE seemed to be quite low, where the teachers had few examples of things they believed could be an effort. For SI it was mostly neutral, there was no pressure to neither use nor not use computers. The FC on the school seemed to be the largest obstacle. It was hard to access computers, and there were too few computers for the learners. The knowledge of using computers was also quite low among the teachers which also could explain why computers have not been used. There were some indications that the learners' computer knowledge and access to computers at home might affect the teacher's usage. The main obstacle to integrating computers in STEM teaching with children from low SES was therefore concluded to be the FC, with the computer literacy of the children being a secondary obstacle. These findings agree with Hwang et al. (2022), Saal et al. (2020), and Chigona et al. (2010) who all conclude that FC is a main determinant for ICT integration in teaching. The latter also concludes that the ICT literacy of the learners is an important factor.

It should also be noted that all factors in the UTAUT framework affect user behaviour, and that if one factor is an obstacle, this could be overcome by increasing the other factors to an extent that compensate for this obstacle. In this study, FC was the main obstacle. This could be overcome by either increasing the FC, or by increasing PE, EE, and SI.

4.3 Experience of computer-integrated lesson

The results from the experience of a computer-integrated lesson suggest that PE was increased, and that EE was decreased. The answers seen in section 3.2.1 show that the teachers thought that the computers made the subject easier to understand, that the computers provided learning which would not happen in a normal lesson, and that excitement was increased. These results could indicate that the teachers were not aware of the possibilities a computer might bring to STEM teaching. Simply observing these advantages could therefore be argued to effectively increase a teacher's PE. One teacher (T2) expressed concerns about teaching with computers. These concerns were time, and the importance of the relationship between the teacher and the children. It was expressed that taking time from regular mathematics teaching would be a problem due to the problem of covering all contents in the curriculum. This teacher did not appear to think that using computers might decrease the time it takes to cover a part of the curriculum, which indicates lower PE, however, compared to the teachers' answers in section 3.1.1, the attitude seems more positive after the experience of a computer-integrated lesson, which could be argued to confirm the increase in PE seen with the other teachers.

As previously mentioned, the teachers expressed a decrease in EE after the experience of a computer-integrated lesson. It was described as 'effortless' and 'easier', as seen in section 3.2.2. These teachers seemed to think that the amount of material available on the internet would increase flexibility and excitement for the children, which would decrease the effort for the teacher. One teacher (T1), who was the only one that planned the lesson herself, expressed that using computers neither increased nor decreased the effort for planning. As with PE, teacher T2 expressed some concerns regarding the curriculum, but also mentioned that the children enjoy using the computers, which might be interpreted as an aspect which might decrease the effort. This is due to the fact that boredom likely has a negative effect on learning (Tze et al., 2016)

The teachers perceived their intention to use computers in STEM as positively influenced by the experience of a computer-integrated lesson. They described that the computers helped broaden content learning, increased joy, increased learning in general, and made the children look forward to STEM classes, which was interpreted as aspects which the teachers valued. While the exact meaning of 'intention' was left undefined, the teachers express that they wish to use computers in their subjects more than before the experience of a computer-integrated lesson. This interview question might not answer *how* an experience of a computer-integrated lesson affects teacher intention, however, it confirms that an experience of a computer-integrated lesson can have a significant effect.

The fact that the teachers' perceptions of PE and EE were affected to such an extent by a short experience of a computer-integrated lesson further indicates that their initial perceptions might not have been very accurate. Even though teachers might have positive perceptions of PE and EE, and that resources are the main obstacle, simply providing resources might not be as effective as also providing a positive experience with a computer-integrated lesson.

To conclude, the experience of a computer-integrated lesson increased PE, decreased EE, and positively affected the teachers' intention to use computers in their teaching. If the main obstacles to integrating computers in STEM subjects are the teachers' views on performance, effort, or general intention, a positive experience of a computer-integrated lesson might be a powerful method of overcoming these obstacles. This agrees with Chigona et al. (2010), who states that most teachers, after initial training, thought ICT was beneficial for learning. Furthermore, these conclusions confirm the findings of Buabeng-Andoh (2012) which suggest that teachers' perceptions are more likely to change if they observe the benefits of ICT, rather than read about them.

5

Conclusion

The aim of this study was to describe the obstacles to using computers in STEM teaching in a context where the learners have low access to computers outside the school environment, as well as to examine how an experience of a computer-integrated STEM lesson could affect teachers' intentions to incorporate computers more in their teaching. Based on the results and discussion in chapters 3 and 4 this study concludes that the facilitating conditions, both resources and knowledge, are the main obstacles to computer integration. The SES of the learners might also have an effect. Furthermore, it was concluded that an experience of computer-integrated lessons can have a positive effect on teachers' performance expectancy as well as effort expectancy, and increases teachers' intentions to use computers in their teaching.

5.1 Practical implications

Based on the findings of this study, several practical recommendations can be made. Firstly, some recommendations are made to policy makers deciding on school curricula. As there is a gap in academic achievement between children with low respectively high SES, and ICT can reduce this gap if used for learning (Chiao and Chiu, 2018), this study recommended that ICT is integrated into the curriculum of STEM subjects. Secondly, as an important finding of this study was that a positive experience of a computer-integrated lesson could have a significant effect on teachers' inclination towards using computers, this study recommends that policy makers provide teachers with continuing education where this type of experience can be had, in addition to education about useful computer software. This effect could also compensate for low facilitating conditions to some extent. Thirdly, as the clearest finding of this study was that the facilitating conditions are crucial for enabling computer integration in STEM subjects, these conditions have to be fulfilled. For this reason, schools need economic funding to be able to create conditions where computer integration is possible. Policy makers, governments, or other institutions are recommended by this study to provide this funding. Finally, the school where this study was conducted is recommended to examine what logistical changes might be made in order to make lessons with computers more accessible.

5.2 Future research

This study suggests that further research should be done in order to strengthen the validity of the results, and to broaden knowledge in the area of study. Firstly, as this was a qualitative study, general conclusions are difficult to make, and it is thus recommended that a similar study is done but with quantitative data. Secondly, this study was conducted in a very specific context, which affects the results. It is therefore recommended that a similar study is conducted in a different context. Thirdly, it is recommended that the conclusions are tested, perhaps by supplying a school with the necessary resources and knowledge, and studying the effects of this, and also to study whether the PE and EE are in fact as high respectively low as concluded in this study.

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A

Appendix 1

A.1 Interview guide

Warm up question
How often do you use computers in your mathematics education? (Number of lessons/year)
Performance Expectancy
How do you think using computers in math classes would affect the learning outcome?
How do you think using computers in math classes would affect the quality of the lesson?
How do you think the difficulty of planning a lesson where the children are to use computers would compare to a lesson without computers involved?
Effort Expectancy
How would you describe the level of difficulty for you as a teacher of using computers in math classes?
Compared to planning a "normal" math lesson, how time consuming would a lesson with computers involved be?
How would you describe the effort for you in a math lesson with computers compared to a lesson without computers?
Social Influence
Are there people who influence you who think you should use computers in math lessons?
Do you think you would use computers in math lessons if others did so?
How would you describe the prestige of using computers in math lessons?
Facilitating Conditions
Do you feel like you have the necessary resources to use computers in math lessons?
Do you feel like you have the knowledge to use computers in math lessons?
Is there guidance on how to use computers in math available to you? Do you have the needed technical support?
How would you say using computers in math lessons fits with the way you like to work?

Children's access to computers
How would you describe the average learner's ability to use computers? Mouse and keyboard? Find information independently online? Use math software? Office software? Describe the lowest as well as highest ability
What computers do you think are available to the children outside school? Computers at home? Smartphones? A place where they can go and use computers? (not school)?
How does the children's ability to use computers affect if you use them or not? If you knew they'd find it easy, would you use them? If you knew they'd find it difficult?
How do you think it would benefit the children if they were more experienced with computers?
To what extent do you as a teacher feel responsible for teaching the children to use computers?
Is there anything else you would like to add?

Table A.1: Interview guide

A.2 Second interview guide

Questions for second interview
How do you think the subject learning compared to a normal lesson?
How do you think the learners' computer knowledge was affected?
How would you describe the effort of doing a lesson like this again? Compared to before the introduction?
How has your intention to use computers in your lessons been affected by this experience?

Table A.2: Guide for the second interview

A.3 Arithmetic lesson

Exploring Factors Using Phet

1. Go to https://phet.colorado.edu/
    a. Search for “Arithmetic”
    b. Press Play
    c. Click on “Factor”
    d. Click on the clock symbol: 

2. Complete level 1 (the left one)

3. In the table below, 3x4 is calculated. How many rectangles are shaded?
    a. How many more rectangles should you shade to get 3x5? Answer: ________
    b. How many more rectangles should you remove to get 2x4? Answer: ________
    c. Discuss if you can use this to complete level 2 and 3.

X	1	2	3	4	5	6
1						
2						
3				12		
4						
5						
6						

4. Play level 2 and 3, record time and score
    Level 2: Time:________ Score:_______
    Level 3: Time:________ Score:_______

Figure A.1: Lesson plan for the Arithmetic simulation.

A.4 Fraction Matcher lesson

Exploring Fractions Using Phet

1. Go to https://phet.colorado.edu/
    a. Search for "Fraction matcher"
    b. Press Play
    c. Click on "Fractions"
    d. Click on the clock symbol:

2. Complete level 1

3. Go back to level 1 and restart by clicking:
    a. Now match two fractions that are not the same. What happens?
    b. Can you use the symbol and number line that appear to decide what you should do to find the right match?

4. Play level 2 and 3, record time and score
   Level 2: Time:_______ Score:______
   Level 3: Time:_______ Score:______

5. Continue playing the levels, see how many you can complete

Figure A.2: Lesson plan for the Fraction Matcher simulation.

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