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Teachers' perceptions of ICT implementation in their mathematics teaching

an international survey study about digital competence

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Abstract

Title: Teacher's perception of ICT implementation in the mathematical classroom and its impact on student achievement. A survey study with a focus on digital competence.
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The following study aspires to identify teachers perception of their use of ICT and their views of its impact on student mathematical achievement. In addition, the study seeks to compare teachers in both North America and Europe how they implement digital artefacts and their perceptions of possible impacts. The empirical material consists of 120 teacher responses to a survey which contains closed and open queries.

The result of this study is that most teachers' perceive they use digital artefacts during their mathematics lessons, there is however a difference in usage between teachers in Europe and North America (NA). Furthermore, most teachers in Europe perceive digital artefacts to have a positive impact on student mathematical achievement. The number of NA teachers' perceiving that the use of digital artefacts has a positive impact on student mathematical abilities is lower. There is also a strong connection between teachers' claimed digital competence and the usage of digital artefacts. The teachers with higher digital competence implement digital artefacts in a more widespread way. A higher digital competence amongst teachers implies an increase in student mathematical achievement.

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1. Introduction

Teachers' neglect to use digital artefacts in mathematical teaching (Genlott & Grönlung, 2015; Swedish National Agency, 2019). This neglect contradicts both results of previous research (Skryabin, Zhang, Liu & Zhang, 2015) and the curriculum (Swedish National Agency, 2018). A survey done in Sweden indicates that information and communication technologies (ICT) implementation does not reach the standards set by the national curriculum (Swedish National Agency, 2019). According to Skryabin, Zhang, Liu & Zhang (2015), the use of information and communication technologies (ICT) in general can improve student mathematical achievement in mathematics amongst other subjects. Even though studies show a positive influence on student mathematical achievements through the implementation of ICT, many teachers' are still opting not to use it. According to Prieto-Rodriguez (2015), most teachers' that use ICT do so in a teacher-centred manner. The reasoning behind teachers' neglect of digital artefacts differs. Drijvers, Boon, Doorman & Reed (2010) presents in their study that some teachers argue that there is a lack of time for planning and integrating ICT whilst others are comfortable with the way their current educating situation looks. However, both De-Witte & Rogge's (2014) and Prieto-Rodriguez's (2014) studies show that teachers do not always have access to ICT even if they wish to use digital artefacts. The lack of equipment is still present even though many schools have emphasized digital development during the last decade (De-Witte & Rogge, 2014). The uneven implementation of ICT across nations creates inequality in education for the students (Genlott & Grönlund, 2015).

Aim and research questions

Even though research shows that teachers neglect to use digital artefacts, there is a need to further investigate the implementation from their perspective and in relation to mathematics education.

- ➢ How do teachers' perceive their use of ICT and can it be connected to their digital competence?
- ➢ How do teachers in different countries perceive their use of ICT in mathematics and its impact on student mathematical achievement?
- ➢ What differences in attitude towards the use of ICT exist between Europe, North America?

2. Theory and previous research

Instrumental genesis

To deepen the understanding of digital competence in the mathematics classroom, I turn to the theory of instrumental genesis (Geraniou & Jankvist, 2019). Instrumental genesis implies that digital artefacts can become mathematical instruments. The digital artefacts possess the ability to become instruments that can enhance a student's mathematical achievements (Geraniou & Jankvist, 2019). These instruments should become a part of students' cognitive schemes and then when these schemes are used, they can support students' mathematical achievements (Geraniou & Jankvist, 2019). The theory uses two dualities to explain digital artefacts and their connection to mathematics, the "artefact-instrument" and "instrumentation-instrumentalisation" dualities. Artefact-instrument refers to the, often tedious, process of how a user turns an artefact into an instrument.

The use of an artefact is by no means a one-way process of the student simply using a tool. According to Haspekian (2005 s. 118) "...the idea of instrumental genesis reflects the fact that using a tool is not a one-way process, there is dialectic between the subject acting on his/her personal instrument and the instrument acting on the subject's thinking".

The second duality, instrumentation - instrumentalisation, refers to a relationship between artefact and user (Geraniou & Jankvist, 2019). The theory indicates that the knowledge of implementation of a tool, instrumentalisation, can affect the thinking and action of the user, instrumentation (Haspekian, 2005). Geraniou & Jankvist (2019) writes that digital artefacts serve an epistemic purpose, which means that the purpose of a digital artefact is to be used and through the use, it is meant to create understanding and/or support learning.

The instrumental approach points out the necessity of using tools and its potential for both teaching and learning mathematics. Using digital artefacts in the form of spreadsheets allows for a deeper conceptual knowledge of the mathematical concepts (Haspekian, 2005). The theory of instrumental genesis is relevant to this study due to its focus on the use of digital artefacts within mathematics. It can serve as support when trying to understand the impact of digital artefacts on student mathematical achievement.

ICT in education

Since the introduction and mass production of ICT countries have invested money to both incorporate digital artefacts into the schools (Ahmed, Clark-Jeovons & Oldknow, 2004) and provide teachers with the proper knowledge to navigate these artefacts. As an example to strengthen the previous statement, between 1999 and 2003 a total of 320,000,000 euro was spent in the UK to provide teachers with the needed training to develop their digital competence (Ahmed, Clark-Jeovons & Oldknow, 2004). Digital competence has been defined as a basic competence area in Norway (Gudmundsdottir & Hatlevik, 2018). This means that alongside other fundamental knowledge, such as writing, reading, oral communication and mathematics, digital skills has been acknowledged as something that should be a part of every subject and grade (Gudmundsdottir & Hatlevik, 2018). This implies the importance of teachers having high digital competence and allowing students to use digital artefacts in their education.

Even though previous research shows that technology is rapidly advancing across the world (Ahmed, Clark-Jeovons & Oldknow, 2004; Gudmundsdottir & Hatlevik, 2018), many teachers still avoid using ICT for various reasons. However, even after the attempt to invest in digital artefacts, some school teachers are expressing dissatisfaction about the lack of ICT availability in the schools (De-Witte & Rogge, 2014; Genlott & Grönlund, 2016; Prieto-Rodriguez, 2015). Since the expansion of technology, multiple countries have seen a need to integrate the use of digital artefacts into their curriculum. Sweden is one of these countries and even though the curriculum, LGR 11, does not specify how ICT is to be integrated, it states that ICT needs to be a part of the students' education (Swedish National Agency, 2018). However, a large part of teachers in Sweden have a negative attitude towards the use of digital artefacts in mathematics (Genlott & Grönlund, 2016). Sweden is not the only country that has teachers that avoid using digital artefacts (De-Witte, Rogge, 2014). Although the reasons for not using ICT differ greatly. Other reasons for not using digital artefacts may be the economy, some countries may therefore not have access to digital artefacts to the same extent. Other countries have teachers who have low digital competence and therefore opt to not use digital artefacts in their teaching (Genlott & Grönlund, 2016; De-Witte, Rogge, 2014). Another reason for teachers' ICT avoidance is the teachers' ability to interpret the curriculum, they can choose what kind of materials to use or not to use. Furthermore, the teachers' own knowledge about learning situations and values have a large impact on how they wish to interpret what materials should be used (Bosco, 2004). Even though there is a subjective interpretation of the curriculums, there are still those teachers that use digital artefacts to improve student mathematical achievement (Ahmed, Clark-Jeovons & Oldknow, 2004; De-Witte, Rogge, 2014).

Swedish National Agency (p. 57, 2018) states that students need to be able to know "Main methods of calculating using natural numbers and simple numbers in decimal form when calculating approximations, mental arithmetic, and calculations using written methods and ICT…". The students are, according to the national curriculum, supposed to be assessed based on their ability to perform calculations with ICT. It is, therefore, critical for the teachers to educate their students on how to operate ICT and its functions in mathematical scenarios. The students are also meant to develop an understanding of how it impacts both their and society's development (Swedish National Agency, 2010). This means that even if teachers do not have the digital competence to use digital artefacts, they need to overcome that in order to teach the students what is required of them by the curriculum. Even though it is explicitly stated in the national curriculum to integrate ICT, some teachers choose to actively avoid using it within their classrooms (Drijvers, Boon, Doorman & Reed, 2010). Their study explains that one of the reasons teachers choose not to integrate ICT is that their current teaching platform is stable and through introducing digital artefacts the stable platform would be unbalanced. According to Prieto-Rodrigues (2015), 52.8% of the 102 teachers responded that the use of ICT took up more time than they had available to them, both for planning and executing lessons. According to the teachers, their work is already complex enough and adding another technique would only complicate it more. It is due to the thought of the complexity behind ICT implementation compared to their own digital competence, some teachers opt to not use it (Drijvers, Boon, Doorman & Reed, 2010). This would perhaps indicate that, even if teachers have the option to subjectively interpret the curriculum, the reason for their choice of not integrating digital artefacts into the mathematics education may be due to that they possess a low digital competence.

The use of digital artefacts extends further than allowing the students to use them during a lesson. Teachers' use ICT to prepare lessons, present information and give instructions using smartboards or data projectors, analyse data from their lessons, through emails or discussions boards help students collaborate. The teacher can use a projector combined with a tool like GeoGebra to show students how to operate tools (Prieto-Rodriguez, 2005). Amongst the various uses of ICT, smartboards and projectors are those that teachers' experience as most comfortable to use. The two teacher-centred tools do not allow students to explore and expand their mathematical abilities but can ease the teachers' job (Prieto-Rodriguez, 2005).

Time centred problems, such as planning and instructing students upon how to use ICT, may be solved with a higher digital competence. The digital artefacts can serve as a more efficient method for parts of the teaching work. It can be used to instruct the students in a productive way. The use of ICT can also shorten the administrative time needed for the teacher (De-Witte & Rogge, 2014). Even if a higher digital competence, in theory, would possibly lower the time required for the use of digital artefacts it does not mean that it will be so in all cases. It does, however, strengthen the statement that high digital competence is necessary for teachers (De-Witte & Rogge 2014; Drijvers, Boon, Doorman & Reed, 2010; Skryabin, Zhang, Liu & Zhang, 2015).

In the study done by De-Witte & Rogge (2014) around 55% of 2413 Dutch students that were observed claim that they use ICT once or twice a week during lessons. However, barely 15% use it every day. These numbers correspond to the study done by Prieto-Rodriguez (2015). In her study (2015), the result shows that more than half of the teachers responded that they often use ICT within their classroom. Although the teachers in Prieto-Rodriguez's (2015) study answered "often" it is not possible to fully connect the results to De-Witte & Rogge (2014) as the term "often" is subjective. However, it does indicate that teachers are using ICT for educational purposes to some extent, to what extent may however vary.

Genlott & Grönlund, (2016) refers to a study, without mentioning the numbers of participants, done in Sweden where one-fifth of the teachers have a negative attitude towards the use of ICT and only one-third show a positive attitude towards ICT. Due to the unknown number of participants, it is not entirely plausible to make any conclusions of Sweden's teachers, or teachers in general from this.

The problem with implementing digital artefacts exists not only in planning the lesson but also during the teaching (Prieto-Rodriguez, 2015). Teachers experience that even after instructing the students on how to use ICT, there may be those who need extra help. An additional problem when allowing the use of ICT according to teachers is that the students may use the tools for other means than learning (Prieto-Rodriguez, 2015). Another issue with the implementation of ICT that research has shown is that few classrooms have student-centred ICT in mathematics teaching (Prieto-Rodriguez, 2015). Instead of student active use of digital artefacts, the teacher uses it to present mathematical topics through projectors and/or smartboards. As reported by the study done by Prieto-Rodriguez (2015), most of the teachers experienced that they had a high digital competence and were therefore comfortable with using ICT. Even so, the teachers fail to incorporate ICT into their mathematical education and thus disallowing the students' opportunities to gain experience working with digital artefacts (Prieto-Rodriguez, 2015). One of the reasons that teachers opt not to use ICT within their classrooms according to Bosco (2004), may be due to the fear of getting replaced. Although, even if the computer has the capacity to handle the mathematical instructions, it is merely a tool. However, according to the instrumental genesis theory, ICT as an artefact the allows the teacher to focus his/her education and allows the students to interact more (Bosco, 2004; Haspekian, 2005).

Teachers who cooperated with other teachers were found to incorporate more ICT into their mathematics teaching than those who worked alone. According to Kiru (2018), the possibility for support in hope to minimize the risks with the use of ICT encouraged teachers' implementation of ICT. In cases where no support was possible, or when an administrator has a vision that does not promote ICT, the implementation of digital artefacts declined.

Not all schools have the economy to use "one-to-one". According to Bosco (2004), the lack of closely available digital artefacts creates inefficiency in mathematical teaching. When the students do not have their own computers and are forced to retrieve them from another place at the school the inefficiency increases. The school budget plays a large role in whether or not the teacher can incorporate ICT into his or her lessons (Bosco, 2004).

Skryabin, Zhang, Liu & Zhang (2015) concludes that because the current students in elementary school are all born after the introduction and spread of technology, it is plausible that their digital competence surpasses both their parents and their teachers.

The impact of ICT implementation on students mathematical achievements

As mentioned above, teachers opt not to use digital artefacts for various reasons. The use of digital artefacts in mathematical education does, however, increase students' achievements. More than half of the teachers in a study (De-Witte & Rogge, 2014) observed that students were more attentive whilst using digital artefacts. The students who, for various reasons, do not get the ability to use digital artefacts score on average lower than the students who have access to it (Skryabin, Zhang, Liu & Zhang, 2015).

The most important part about ICT implementation is the how "...since teachers can use: good materials well; good materials badly; bad materials well and bad materials badly" (Ahmed, Clark-Jeovons & Oldknow, 2004, s.326). This statement does, however, challenge the idea of digital artefacts impacting students mathematical achievements. De-Witte and Rogge (2014) argue that a lower score when comparing high and low ICT using schools is not always because of the lack of ICT. It could instead possibly be tied to the characteristics of students, teachers, schools and districts and the overall digital competence of the users (De-Witte and Rogge, 2014).

Thorvaldsen, Vavik & Salomon (2012) concluded that there was no clear correlation between using ICT and improvement on students mathematical achievement. However, what they did conclude was that depending on how digital artefacts were used by the teacher, student mathematical achievement either improved or deteriorated. Another connection was made by Thorvaldsen, Vavik & Salomon (2012), between a teachers' attitude towards digital artefacts and the impact it had on student mathematical achievement. The teachers that had a negative attitude towards digital artefacts but continued to use it, argued that it is a tool used at the expense of other materials. When comparing two control groups in their study, Thorvaldsen, Vavik & Salomon (2012) found that the teachers' with a better mastery of mathematics would rely more on the use of digital artefacts. Their study also showed that those teachers' with good mathematical knowledge and a high digital competence would continue to use digital artefacts in such a way that it increased the students' achievements (Thorvaldsen, Vavik & Salomon, 2012). This implies that the mere introduction of technology does not lead to any improvements to the students' results (Genlott & Grönlund, 2016). It is important that the teachers using ICT has high digital competence and knows how to incorporate digital artefacts into their teaching. It is shown that through large competence and proper use of digital artefacts the quality of mathematical education can improve student mathematical achievement (Ahmed, Clark-Jeovons & Oldknow, 2004). According to Skryabin, Zhang, Liu & Zhang (2015), the use of digital artefacts both at school and at home had positive influences on the achievements of students. In their study, schools in Korea were compared to each other, but also Korea to other nations. The results of the study showed that students with high ICT implementation both at home and in school had better scores than those with low implementation in not only mathematics but also reading, science and English. Similar results can be shown in other countries like the Netherlands and France (Ahmed, Clark-Jeovons & Oldknow, 2004; De-Witte, Rogge, 2014).

Through the use of digital artefacts, students are given an opportunity to interact with the classroom in a different way than with pen and paper (Thorvaldsen, Vavik & Salomon 2012). Increase in student interaction with the teacher, student and the mathematical problem itself can be seen in the study done by Drijvers, Boon, Doorman & Reed (2010). The interaction that can be seen increased is idea generation, comparison, evaluation and also student-teacher interaction opportunities. This sort of interaction may improve the students' conceptual understanding of mathematical concepts (Granberg & Olsson, 2015). Digital artefacts can provide an explorative learning environment that provides opportunities for reflection amongst students and should be seen as a new semiotic system according to Thorvaldsen, Vavik & Salomon (2012). It is through this reflection that students mathematical abilities improve. The reason why the students' abilities improve may be due to the ability to make decisions within the digital artefacts. When the student is directed and told what to do when using digital artefacts, they are not given an opportunity to improve their knowledge (Thorvaldsen, Vavik & Salomon 2012). However, the use of digital artefacts is not limited to in-classroom use. According to Lowire (2005), the out-of-school use of digital artefacts can increase students mathematical achievement. Lowire (2005) observed a student in an out-of-school context in which the student was presented with a game that required him/her to overcome a series of challenges. These challenges were personalised in an environment that allowed for open-ended problem-solving. What was observed was that the students' ability to solve the problems presented within the game-playing scenario increased significantly in contrast to their mathematical performance in school. The student was also found having a desire to spend a considerable amount of time out-of-school with the problems, providing that they were embedded in rich contexts (Lowire, 2005). Whilst this supports that the use of digital artefacts may increase student mathematical achievement it does not indicate that teachers should allow students to play games during their education. What also needs to be taken into consideration is that this study only followed the case of a single student, which can in no way be used as a general statement for all students.

A problem with the difference in the implementation of digital artefacts between teachers, as previously presented, is that it creates a difference in the education given to the students. Some students are given the ability to work with technology whilst others, perhaps because of their teachers' view of ICT, do not get the ability. It is therefore essential to provide these teachers with the necessary tools to avoid the currently existing inequality (Genlott & Grönlund, 2016).

Teachers' digital competence

Digital competence is a vital key for a teacher to possess if they hope to master the implementation of ICT and in return use it to improve student mathematical achievement in mathematics. Digital competence can be found in three areas according to Gudmundsdottir & Hatlevik (2018). A teacher can possess a generic digital competence which includes basic knowledge of how to navigate the digital artefacts. The second level is a subject/didactic digital competence which allows the user to apply ICT in their specific subject in order to enhance education. Lastly, there is a profession. oriented competence involves the use of ICT outside of the classroom, for example, school-home communication (Gudmundsdottir & Hatlevik, 2018).

In general, teachers lack the digital competence needed to navigate the technology-heavy society (Ahmed, Clark-Jeovons & Oldknow, 2004). According to Gudmundsdottir & Hatlevik, (2018) one of the reasons for insufficient digital competence may be due to the lack of education. Furthermore, teacher students' report a lack of training in the use of digital artefacts (Gudmundsdottir & Hatlevik, 2018). Having a higher digital competence in the three areas would enhance their teaching (Gudmundsdottir & Hatlevik, 2018; De-Witte & Rogge, 2014). Teachers' with high digital competence have been found to use ICT at a larger extent in the classroom. The teachers' with a high digital competence also allow their students to use ICT during the lessons (Kiru, 2018). A teachers' preparedness for the lesson shows no correspondence to ICT implementation. However, a higher level of preparedness could be linked to teachers experiencing a lack of compatibility with ICT. A high preparedness level was also linked to a 15% reduction in ICT implementation(Kiru, 2018).

With the integration of ICT teachers' are presented with a number of choices. They have to choose between a variety of different tools available to them. digital artefacts can be used for calculations, portfolios, spreadsheets, online workbooks, quizzes and allowing students to explore mathematical concepts (Thorvaldsen, Vavik & Salomon 2012). The use of explorative digital artefacts has been shown to be correlated with student mathematical achievement (Thorvaldsen, Vavik & Salomon 2012). Granberg & Olsson (2015) argues for the importance of the didactical design of the lesson. They indicate, as previously presented, that the mere introduction of ICT will not improve student knowledge Such a design would be small groups of students focusing on reflection and interaction with the help of digital artefacts. The use of ICT in such a scenario spurs the development of a conceptual understanding of mathematics rather than procedural knowledge (Granberg & Olsson, 2015).

Research shows that students achievements improve when the students are given the ability to learn through digital artefacts. Dynamic software that allows the student to visualize, for example, functions and follow the entire process of solving the problem is important for their development. The software that allows for exploration and depth are those that allow the student to develop a conceptual understanding of the mathematical strategies (Thorvaldsen, Vavik & Salomon 2012; Granberg & Olsson, 2015).

3. Method

In this part of the study, the survey, method of analysis, sample and ethical principles are presented.

The survey

In this study a survey isu sed to answer the research questions. The survey consists of ten questions to map teachers' use of digital artefacts and their own interpretations of ICT impact on student mathematical achievement. These questions are interconnected to create possible causal connections between them. The first question of the survey is meant to uphold a good research practice (Appendix A; Swedish Research Council, 2017). Seven of the questions in the survey are multiple-choice questions using closed queries (Bryman, 2015). These questions are used to allow the teacher to easily answer questions like their ICT implementation, familiarity with ICT, nationality and their perceptions if ICT affects student mathematical achievement. Questions 3,4,5 are close-ended questions that touch upon ICT competence and teacher implementation of digital artefacts within the mathematics classroom. Question 6 is an open-ended question that allows the teacher to expand upon how they use ICT within their mathematical education. Question 7 and 8 are close-ended questions that allow teachers' to voice their perceptions of ICT impact on student mathematical achievement. Question 9 and 6 is open-ended and allows teachers to explain how they believe ICT impacts student mathematical achievement (Bryman, 2015). When posting in the Facebook groups, the times were well-chosen, at 6 pm CET and 6 pm EST respectively, this was done in an attempt to draw more people in. After the initial post, there have been in addition two more posts, to try and gather as many respondents as possible.

Participants

It was the aspiration of this study to investigate the difference on an international level, however, due to the fallout from major parts of the world it was narrowed down to Europe and North America. In this survey, the principle of probability sample (Bryman, 2015) was applied. This was done in an attempt to be able to make sweeping statements about teachers ICT implementation. It requires a cluster sample that is truly randomized and not chosen. To apply the randomized factor upon this survey respondents have been found in three different ways (Bryman, 2015).

Firstly all the teachers that I personally know have been asked to participate in the survey. These teachers have then been asked to spread the survey to those that they personally know. These first two methods of sample choosing would end up being a snowball sample (Bryman, 2015). A snowball sample can not be used to make sweeping statements. Therefore the number of teachers that were personally contacted were limited to a small number. The last method is the one that has gotten the largest diffusion. Different Facebook groups, all of which allow and encourage teachers to discuss mathematics as a subject in school, have been used to ask teachers of different nationalities to participate in the studies. To find the groups, the phrase "Math/Mathematics teachers" have been used in Facebooks own search engine, the setting has then been set to "groups". There question to participate was asked in a total of 9 different groups. When searching for groups there were many groups that were not selected due to them not being for specifically for teachers. All of the nine groups required that you either are a teacher and or a teacher-student to enter. To enter you had to write an application in where you wrote your current school or university and also what you teach (both subjects and grades). Those that teach mathematics to children that are currently enrolled in upper elementary school (ages 9 to 13) were asked to participate in this voluntary survey. Since this is a study about mathematics teachers use of ICT, all those who do not have a degree and teach mathematics in elementary school have been asked to not participate in the study.

To make sure that all the participants had the same base level of understanding of what ICT meant, the post provided a clarification regarding the concept. The provided information read as follows: “Information and communication technologies (ICT) indicates the usage of technological devices. Cellphones, computers and smartboards are examples of what falls into this category”. These participants are teachers from Europe and North America. Due to being Facebook groups, it was not possible to determine exactly what countries are represented amongst those that read the post. However, the teachers will fall into categories based on their answer to Question 2 (appendix A).

Ethical principles

By following the guidelines of good research practice several precautions have been made (Swedish Research Council, 2017). These precautions have been made to make sure that the respondents are voluntary, their identities are anonymous and that everyone could choose to participate and decide about their own answers should be used or not. This has been done through the post that all respondents have had to read before participating in the study. This has also been made clear in the form of a survey question (Appendix A). Due to this being an internet survey where no names are revealed there is no need to take extra steps to ensure confidentiality further (Bryman, 2015). As an extra step to hide any possible online traces in the form of IPv4 addresses a third party site has been used to set up the survey. The results of the survey shall and will only be used for the purposes of research (Bryman, 2015).

Data analysis

To answer the research questions in this study, data was analyzed using mixed methods. The first method was to structure and create descriptive statistics in frequency tables (Bryman, 2015). The close-ended questions had been analysed by the help of a coding template. The template was created for the purpose of efficiency and simplicity. The template assigns each alternative in all of the question a specific code that will then be possible to put into the frequency tables. These codes were structured by first assigning the letter “Q” followed by the number of the question. “Q1” = Question 1. After the initial number, a second number was added which indicated what alternative of that question was chosen. “Q43” = Question 4, alternative 3. After the template was done, each of the 130 respondents answers was coded. Once the coding was done they were inserted into frequency tables to create descriptive statistics (Bryman, 2015).

However, to be able to answer the research questions of this essay the close-ended questions needed to be tied to a “why” and “how”. This will be done through the analysis of the open-ended questions. The open-ended questions have been created in such a way that there plausibly will be correlations between them and the close-ended ones (Bryman, 2015). Due to the nature of the open-ended questions, they do not fall into the same way of analysation as the close-ended ones. They will therefore instead be analysed thematically. To be able to spot possible patterns in the data, a procedure created by Braun & Clarke (2006) will be followed. The 6 phased procedure created by Braun & Clarke (2006) is as follows:

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

Figure 1, The six phases of thematical analysis (Braun & Clarke, 2006 s.16-23).

Through this thematic analysis, a total of 11 themes were created. 6 out of these themes map the implementation of ICT in the mathematics classroom. The remaining 5 themes indicate the teachers' view of ICT impact on teacher achievement.

4. Results

The results of this study show that teachers perception of their ICT implementation has a spread and that there is a difference between the continents. According to 63.3 % of teachers that participated in the study, the teachers perceive ICT has some form of impact upon student mathematical achievement. There is a difference in attitude between North American (NA) teachers and European teachers, which is that European teachers have a more positive attitude towards ICT.

First, answers from the quantitative analysis will be presented in the form of descriptive statistics (Bryman, 2015). After the quantitative analysis of the results, the two qualitative questions be presented.

Below there are several tables displaying codes. The meaning of the codes can be found in Appendix B.

Teachers' perception of their digital artefact implementation

The results show that there is a difference in ICT implementation between NA teachers and European teachers (Table 2). Generally, teacher's in NA use digital artefacts to a lesser extent than those in Europe. Teachers that use ICT less than 10% in their mathematic education is 20% in Europe whilst 32.5% in NA.

Table 1 Digital artefact *implementation*

Code (Appendix B)	Total %	North America (40)	Europe (80)
Q51	23.9% (28)	32.5% (13)	20% (16)
Q52	37.6% (44)	35% (14)	40% (32)
Q53	24.8% (29)	17.5% (7)	27.5% (22)
Q54	4.3% (5)	5.0% (2)	3.8% (3)
Q55	3.4% (4)	2.5% (1)	3.8% (3)
Q56	0%	0%	0%
Q57	6% (7)	7.5% (3)	5% (4)

Most teachers have used digital artefacts in their mathematics teaching. However, the teachers that stated that they have never used digital artefacts in mathematics education are 5% in Europe and 7.5% in NA. 4 out of the 120 teachers reported a lack in time to integrate digital artefacts into the mathematical education. The category Europe has 27.5% of the teachers estimate their implementation of digital artefacts in mathematics to 26-50% whilst in NA the number of teachers reaching the same implementation is 17.5%. The 7 teachers that have not used ICT in their education all of them expresses a wish to use ICT in their education. They are not alone in expressing a wish to use digital artefacts more than they currently are.

A total of 77.5% of the teachers participating in the study express a will to expand their use of ICT during their mathematics teaching. Although, some of them explain that they do not have confidence in their own abilities to use digital artefacts in other ways than they are currently doing. These teachers are those that either falls into the theme “Flat Software” or “Teacher-implementation” which means they are not using any “Deep software” in their teaching.

Teachers’ perception of digital artefacts impact

The results show a difference in attitude towards how digital artefacts impact student achievement. According to the results (Table 2), 57.5% of the teachers believe that the use of digital artefacts impacts student mathematical achievement positively (Table 3).

Table 2 *Perception of ICT impact on achievement*

Code (Appendix B)	Total %	North America	Europe
Q81	57.5% (69)	42.5% (17)	65% (52)
Q82	5.8% (7)	12.5% (5)	2.5% (2)
Q83	19.2% (23)	27.5% (11)	15% (12)
Q84	11.7% (14)	12.5% (5)	11.3% (9)
No Answer	5.8% (7)	5% (2)	6.3% (5)

However, when comparing teachers in NA to Europe there is a distinct difference in attitude towards ICT impact. In Europe, only 2.5% of the teachers' see the influence of digital artefacts as negative towards the students' achievements. When looking at the NA teachers the number goes up to 12.5%. The difference between teachers in NA and Europe, when comparing the positive attitude towards the influence of ICT, is large. This is another vital difference between the two continents as teachers in Europe, in general, perceive the use of ICT as more beneficial than the teachers' in NA (Table 3). Out of the teachers who believed digital artefacts have a negative effect on students mathematical achievement, 4 explained that they had always used pen and paper and perceived for various reasons that pen and paper were better. Respondent 69 wrote the following "Math is best learned with a paper and pencil.". Furthermore, Respondent 51 believes that digital artefacts have a negative impact on student achievement due to "The reasoning is that the students need to know math facts with automaticity.".

There were those teachers that expressed uncertainty about the possible impact of ICT on student mathematical achievement.

> I believe our students are too overstimulated with technology. They use it as a crutch to not have to understand the basic concepts, and in doing so struggle with developing an understanding of the more advanced concepts. I know some teachers use it in lieu of teaching a physical lesson to the class at large. It gives me major concern that students dont get the opportunity to have a structured learning experience and also then to have truly independent practice that they work on their own at home. (Respondent 74)

Even though this teacher expresses doubt as to the impact of digital artefacts on student mathematical achievement, they have also answered that their ICT implementation is between 51 and 75%.

Teachers' digital competence

The results show (Table 4) that 63.3% of the total 120 teachers perceived that they were comfortable with using ICT in general.

Table 3 *Comfortability with ICT*

Code (Appendix B)	Total %	North America	Europe
Q41	63.3% (76)	65% (26)	62.5% (50)
Q42	8.3% (10)	15% (6)	5% (4)
Q43	18.3% (22)	10% (4)	22.5% (18)
Q44	10% (12)	10% (4)	10% (8)

Only 8.3% (10) indicated that they did not have confidence in their digital competence. An example of one of these teachers' gave was "fear of new technologies" (Respondent 81). However, out of the 10 that did not have a high digital competence only 1 perceived digital artefacts to have a negative impact on student mathematical achievement. Another reason for a lack of digital competence was given by respondent 93 was "Lack of training and resources

make it hard”. There was a larger proportion of teachers that were uncertain of their own digital competence, 29.1% either felt confident “Sometimes” (18.3%) or “Most of the time” (10%) (Table 4).

Digital artefacts in teaching in relation to student mathematical achievements

The question “Please elaborate upon how you (or why you don’t) use ICT during your math lessons”, resulted in 6 themes. These themes were “teacher-centred”, “student-centred”, “Flat software”, “Deep Software”, “Sharing” and “Unavailable tools”.

This study does not aspire to answer the question if student mathematical achievement increase or not through the implementation of digital artefacts. The study does, however, aspire to present teachers own perceptions if their students have increased their mathematical achievement through the implementation of ICT.

Teachers favour the use of “flat software” over “deep software”. The themes “flat software” and “deep software” was developed when analysing the open-ended question 6 through Braun & Clarke’s (2006) 6 phases of thematical analysis. “Flat software” encompasses websites or programs that only allow for a singular answer to be put in, either correct or incorrect. The flat software does not allow the students to delve into a problem and through it find a conceptual understanding of the mathematical concepts. Underneath are a few examples given by teachers that fall into the category of “flat software”.

Out of the 95 teachers that elaborated as to how they used ICT within their classroom, 48 states that they use software that falls into the flat software category in some way and 13 uses software that falls into both flat- and deep software categories. 35 of the teachers’ that solely uses flat software all perceived that their implementation of digital artefacts impacted student mathematical achievement in a positive way. For instance respondent 3 expressed themselves in this way “Example: Elevspel.se, meaning pure proficiency training” (Respondent 3, translated). Furthermore, respondent 77 explained that “I didn't find the right tools except for Kahoot”. Both “Elevspel.se” and “kahoot” has been looked further into which showed that both platforms fall into the “Flat software” category due to their inability to provide exploration opportunities for the students.

Only 17 of the teachers explained that they use digital artefacts as deep software. Out of the 17, 12 used both flat and deep to further the students’ mathematical abilities. Here are two examples of teachers that fall into both categories; “I used ITC in evaluating (kahoot), in learning (math learning center)” (Respondent 56) and “We have one to one devices for our students so I work to incorporate those into my lessons at least once per week if not more. Using demos for lessons, using quizizz and kahoot for review games. Also having students work collaboratively on projects through google docs and google sheets.” (Respondent 1). This respondent (58) however, solely falls into the “deep software” theme; “Use GeoGebra and desmos to visualise concepts. Teach students to use both as a tool in problem solving.”. The websites and programs, math learning center, GeoGebra and desmos have all been looked into and they provide the students with opportunities for exploration, thus they fall into the “deep software” category. The deep-software is as explained before, those that allow for exploring not only the concepts but also the correct and wrong strategies for certain mathematical problems. Desmos, GeoGebra, Math Learning Center are examples of what a deep-software is. The 12 teachers that only falls into the “deep software” category, all express in question 8 of the survey that they perceive an improvement of student mathematical achievement through the use of digital artefacts. The two categories soft and deep is only a measurement of the software themself and not how the teachers use them. This study does not research whether or not the use of a certain software actually does increase student mathematical achievement. It is entierly plausible that a teacher using a program that falls into the flat software category can increase their students mathematical achievement. However, according to previous research students increase their mathematical knowledge and achievement better through deep software (Thorvaldsen, Vavik & Salomon, 2012)

The theme "teacher-centred" indicates teachers who perceive that they use digital artefacts during the mathematics lessons. This can be done through a presentation, showcasing the use of certain digital instruments, using flat or deep software to explain certain mathematical concepts or showcase calculations through Excel. 38 out of the 95 participants fall under the theme "Teacher-centered" and out of those 38 the most common use is presentations at 20. Furthermore, 14 of the 38 teachers that fall into the "teacher-centred" category do not fall into any other theme. These 14 do not provide any additional information as to how, or if, they allow students to use digital artefacts.

Only 4 teachers use digital artefacts for sharing information between themselves and students. The sharing is either done through google docs/sheets (3) or google classroom (2). A total of 8 out of the 95 teachers fell into the theme "Unavailable tools". These 8 teachers do not have access to any digital artefacts and explain that their schools do not provide them with the means necessary to hold lessons containing digital artefacts. All of these 8 people answered that they wish to use more digital artefacts in their mathematical teaching as they perceive ICT as something that improves students mathematical achievements

Digital artefacts impact on student mathematical achievement

In the thematic analysis done to answer the question "If you believe that the students' mathematical abilities are affected by the use of ICT in any way, please elaborate on how. Example: Their conceptual understanding has improved/it hasn't.", 5 themes were analysed. These themes were "Increased conceptual knowledge", "It affects in a negative way", "Increased Motivation", "Increased Results" and "It does not affect students mathematical achievements".

The five themes that originated from the thematic analysis of question 9 were evenly split between them in numbers, with the largest group believing that the use of digital artefacts increases student motivation toward mathematics as a subject (14), which in turn can increase student mathematical achievement. A number of teachers (12) explained that through the use of digital artefacts they could see an increase in student conceptual knowledge in various fields of mathematics, which would then increase student mathematical achievement. The teachers' (6) explanations were that student mathematical achievement can increase through digital artefacts when students are granted visual aids which helps them understand and complete the assignments and in return increases their conceptual knowledge. Others (3) believe that through digital artefacts ability to give immediate feedback, students are able to quickly grasp what is right and what is wrong which in the long term increased their conceptual knowledge.

There is a proportion of teachers that perceive that students achievements either are not affected or affected in a negative way. A total of 19 teachers' fall into these two themes and only one of them explains further than "It doesn't" or "ICT is better taught through pen and paper". The one teacher that believes that ICT may affect students mathematical achievements in a negative way explains that the students are already overstimulated by technology. By allowing students to work with digital tools in mathematics students do not learn the mathematical concepts by themselves, they rather use the artefacts as a crutch to not have to learn the mathematical concepts. Respondent 74 continues to explain that through digital artefacts students are not given the opportunity to have a structured learning experience.

The theme "Increased Results" had 10 responses from teachers. Only a few explain further as to why they believe the student's results have improved. An example from respondent 18 is "I feel that using computers allows me to increase their conceptual understanding of math concepts". Furthermore,

> I believe that some children who struggle and get very anxious about some mathematical concepts are able to relax while using technology and their learning greatly improves.2. Improves students problem solving skills. 3. Provides an excellent modality for different learning styles. (Respondent 96)

It is perceived that through the engagement that students may feel towards digital artefacts that their motivation increases and therefore their results do too. Another explanation is also that it is simpler and faster which in return allows students to practise more and that this combination yields increased results for the students.

5. Discussion

The purpose of this study was to identify teachers' use of digital artefacts in the mathematical classroom in relation to students mathematical achievement. The results of this study show that there is a difference in ICT implementation between Europe and North America. This difference indicates that European teachers uses digital artefacts to a greater extent than the teachers in NA. There is also a slight difference in perceptions, where European teachers' view of ICT and its impact more positively than their NA counterparts. The results also showed a correlation between digital competence, ICT implementation and view upon its effect on student mathematical achievement, which will be discussed in this section.

Results discussion

Most of the teachers (51.5%) claim that they use digital artefacts between 0 and 25% when teaching mathematics. Only a smaller percentage (7.7%) uses it between 50% and 90% of the time. These results could correspond to what De-Witte, Rogge (2014) found in their study. However, what is not made clear within the limits of the questions used for this survey is the spread of the implementation. A teacher using ICT between 11 and 25% could still be using digital artefacts every day, just a smaller proportion split up, whilst a teacher using ICT between 25% and 50% could use digital artefacts during one or two days. There are several indications found both in previous research and the results in this study as to why teachers opt not to use ICT, however, the difference between teachers in Europe and NA in terms of ICT implementation requires further research to be able to find a reason as to why it exists and if it does exist.

Furthermore, there are 6% of the participating teachers that are not being given access to digital artefacts. Even though there exists a shortage of digital artefacts, neither previous research presented in this study or this study strives to answer the question of why it exists. However, it is an important issue to address since this shortage is a hindrance for teachers trying to increase their digital competence. Even if these teachers were given access to digital artefacts, there are no guarantees that they would have the digital competence to use them in a way to increase student mathematical achievement. Neither is there a fail-safe way to use digital artefacts in such a way that it increases student mathematical achievement.

This study shows that most teachers' have a positive view of using digital artefacts whilst only a small proportion has negative opinions about ICT and its impact (Table 2; Table 3). Although, there is a difference between European and NA teachers digital artefacts implementation and the view of its impact on student mathematical achievement. Out of the 40 teachers from NA, 12.5% said that they believe digital artefacts to have a negative impact on student achievement. Similarities can be found in Genlott & Grönlunds (2016) results, 20% of Swedish teachers have a negative attitude about the use of digital artefacts and only one third had a positive attitude. However, this does not correspond to the results of European answers. 65% of the European teachers believe that digital artefacts have a positive impact on student mathematical achievement and only 2.5% believes it has a negative impact. However, the study referred to by Genlott & Grönlund (2016) was made in 2014. Since then schools have invested more money to incorporate more ICT (Ahmed, Clark-Jeovons & Oldknow, 2004; De-Witte, Rogge, 2014). Teacher students are expressing a lack of training with digital artefacts (Gudmundsdottir & Hatlevik, 2018). A lower digital competence has been shown to indicate a more negative attitude towards the use of digital artefacts whilst it is the opposite for those with a higher digital competence (Kiru, 2018).

Many teachers, 57.5%, state that the use of digital artefacts impacts student mathematical abilities in a positive way. The theory of instrumental genesis (Haspekian, 2005) was used in this study to solidify the importance of digital artefact implementation. Look at the results in relation to the theory used in this study, the use of digital artefacts can increase student mathematical achievement. The teachers explained that they believed ICT to enhance students' conceptual competence, motivation and even results. This may, however, be an effect of the teacher rather than ICT itself as is suggested by De-Witte, Rogge (2014) and Thorvaldsen, Vavik & Salomon (2012). It was not this studies aspiration to investigate whether or not the use of ICT actually improves student mathematical achievement, but rather if teachers' perceived it to be so or not. To provide a better understanding of whether or not the implementation of ICT increases student mathematical achievement, further research has to be done. A total of 7 teachers perceive the effect of ICT implementation as negative and out of these 7, 4 claim that the use of pen and paper are superior in comparison. This view is not supported by the previous research as it would rather indicate the opposite, that the use of ICT has a higher potential than pen and paper (De-Witte & Rogge, 2014). However, previous research is conflicted if it is the implementation of ICT that increases student mathematical achievement, or if it is how the implementation is done. As previously mentioned by Ahmed, Clark-Jeovons and Oldknow (2004), tools can be used in a bad or a good way. As has also been discussed by De-witte and Rogge (2014) the mere implementation of ICT does not seem to be a causal connection to student mathematical achievement increasing. Rather, it seems to be the teacher and their own knowledge and implementation that plays a larger role. Even though teachers use deep software, does not mean that they use it in a way that actually furthers the student mathematical achievement. It is therefore needed to further investigate the actual implementation of digital artefacts and in which cases they do or do not increase student mathematical achievement.

The results of this study show that 63.3% of the teachers perceive that they are confident enough in their abilities to use digital artefacts during mathematics teaching. It is only in this group of 76 teachers that we find those that use deep software. The use of deep software requires a teacher to have a higher digital competence to be able to utilize it in a way that it encourages and enhances student learning (Gudmundsdottir & Hatlevik, 2018; Kiru, 2018). As has been indicated by previous research, having a higher digital competence allows you to navigate the more complex digital artefacts (Geraniou & Jankvist, 2019; Gudmundsdottir & Hatlevik, 2018). There might be a correlation between a high digital competence and the implementation of deep software, which is by nature more complex to navigate (Thorvaldsen, Vavik & Salomon 2012). To fully answer this question, further research is needed on the subject.

Furthermore, teachers opt to use flat software that requires a lower digital competence than the deep software which requires a higher digital competence. This would be in contradiction to the results of previous research which suggests that the use of deep software allows for a better conceptual knowledge (Thorvaldsen, Vavik & Salomon 2012; Granberg & Olsson, 2015). However, as the instrumental theory (Haspekian, 2005) suggests, using digital artefacts is not a simple matter. It requires knowledge or in this case, digital competence to operate in a way that enhances student mathematical achievement. The reason so few teachers' opt to use the deep software may be due to their own digital competence. In contrast to deep software, the flat software tells a student what to do and therefore removes a part of the learning process. Even so, out of the 35 teachers that solely uses flat software all 35 perceives that their use of digital artefacts increases student mathematical abilities. This could possibly contradict the idea that merely introducing digital artefacts will not have an impact on student mathematical achievement (Thorvaldsen, Vavik & Salomon, 2012; De-Witte & Rogge, 2014).

Method discussion

The focus of this study was to research teachers perceptions towards their use of digital artefacts and its possible impact according to the teachers on student mathematical achievement. Thus this study has predominantly used quantitative methods of collecting data. However, there is a need for further research about the actual impact of digital artefacts on student mathematical achievement. The research questions presented in this study combined with the predominant use of quantitative analysis could not answer if student mathematical achievement increases, only if teachers perceive it so. It is therefore vital to further research the "If" and "how" to further understand the correlations between digital artefact implementation and student mathematical achievements.

A total of 130 teachers answered the survey, however, due to the small number of participants from Asia, Africa and Australia, they have been excluded when answering this essay's ten research questions. The reason being that no valid comparison can be done with this few amounts of respondents originating from those parts of the world. A total of 130 teachers from across the world participated in the survey, whereof 10 of them have been excluded from the comparison.

Furthermore, when clustering all of Europe and North America together to make a general statement it can possibly create a skewed picture. Due to the small numbers of participants in this study, it isn't possible to create or make a general statement about teachers in either region. As Europe consists of different countries and NA of different states that all have their own curriculum, there can be differences on a national level that affects the results of this study. It would, therefore, be beneficial to further research the individual countries and states to further create a better representation of teachers ICT implementation and its effect on student mathematical abilities in that specific country or state.

The choice of using a quantitative survey came with a few advantages. It allowed for a broader sample and the possibility of researching on an international basis without having to be there in person (Bryman, 2015). This study was meant to give an international comparison, however, due to low amounts of respondents from several continents, the focus had to be changed. Here there is also a possibility for further research as this study only shows results from North America and Europe. Another advantage is the low monetary need, using a digital survey allows for the use of a single computer and therefore greatly limits the funds needed to follow through with the research (Bryman, 2015). For the quantitative part of the study, there is no "interviewer effect", as there is no need to interpret the answers given by the respondents (Bryman, 2015). It is however needed to interpret the answers given in the two open-ended questions, however, through the use of Braun & Clarke's (2006) method of thematical analysis, there is no need for great interpretation. Bryman (2015) explains that one strength of the survey is that it allows the respondent to answer when they have the time to do so, rather than forcing a respondent to answer upon scheduled times.

Even though using an online survey allows for a broader and greater range of respondents, there are no guarantees for respondents. In the case of this study, using Facebook groups was initially thought to be a great idea as it would reach many teachers from different continents. It did however only provide 140 respondents, whilst close to 50000 read the posts providing the information about the survey. Whilst the use of a digital survey is a great tool, using Facebook groups has not proven to be effective, even though there have been several posts at specific times to make sure that it reaches as many as possible (Bryman, 2015). Another issue that was discovered after the launch of the survey, is the small amount of time spent on the surveys open-ended questions. Some of the respondents even skipped the questions that required them to write rather than just press a button with a pre-written answer. It is possible that this is an effect of using an online survey. The 2 "open queries" allowed the teachers to further explain their answers from their own perceptions. Unfortunately, these two questions did not yield as much information as was hoped due to either mostly short answers or even skipping of the question. Unfortunately, the use of a survey does not provide the possibility to use follow-up questions (Bryman, 2015). However, the aspiration of this study was only to find out about teachers own perceptions and therefore there is no need to use follow-up questions.

The question of reliability, validity and credibility is important to raise. To make sure that there is strong reliability the necessary steps of creating and analysing the survey have been taken (Bryman, 2015). The reliability could be strengthened with another survey containing the same amount of people represented from Europe and North America. There was unfortunately not enough time to conduct another survey of this fashion. Although, even if another survey would be constructed there is still a possibility that there would be a difference in the answers (Bryman, 2015). The reason for this is that the teachers perspective are influenced by their own digital competence and if the digital competence would increase or decrease there would be a difference in results from this study (Gudmundsdottir & Hatlevik, 2018).

To ensure the measurement validity the questions in the survey was created in such a way that they were correlated. Questions 3,4 and 5 all have to do with the teachers' digital competence and questions 7,8 and 9 have to do with their perception of digital artefacts impact on student mathematical achievement (Appendix A; Bryman, 2015). If different answers would be given by the same respondent, that would indicate that they have misunderstood something and their answers would be forgone. These questions are all connected to the teachers' perceptions of both their own digital competence and if they believe ICT to have an impact on student mathematical achievement, thus they answer the research questions. To avoid interfering with internal validity (Bryman, 2015) of the study, there has been no attempts in finding causal relationships.

The credibility of this study can, just like any other study, be questioned (Bryman, 2015). However, several of the results correspond to previous research. There has been no tampering with the results and all the numbers have been checked multiple times by multiple people (Bryman, 2015). However, as this study relies on the honesty of subjective perception, this can be seen as something which must be viewed with scepticism (Bryman, 2015). It is however due to this essay being specifically meant to identify these subjective perceptions of teachers that the results are credible.

Conclusion

The aspiration of this study was to identify and compare how teachers in Europe and North America perceive their implementation of digital artefacts and their views of a possible impact upon student mathematical achievement. The results indicate that there is a difference in attitude concerning ICT between teachers in NA and Europe. Teachers in Europe have a more positive attitude towards both using digital artefacts and a more widespread perception that digital artefacts affect student mathematical ability in a positive way. However, there is a strong overrepresentation of flat-software implementation, both amongst the European and NA teachers, the flat software does not allow students to develop their understanding of mathematical concepts as well as the deep software does. The conclusion is therefore that teachers need a higher digital competence in order to be able to utilize and implement the deep-software.

Future research and teaching

To further research the possible impact of digital artefacts upon student mathematical abilities it is required to study the "if" and "how". As previously mentioned this study does not answer if student mathematical achievement is actually improving through the use of digital artefacts and even if teachers perceive it so it is necessary to properly research if their knowledge is increasing or not.

Another possible angle to further research is to investigate how or if teachers digital competence can be connected to teachers' digital artefact implementation and how that impacts student mathematical abilities. It would also be interesting to have a more fine-grained comparison between nations of their digital artefact implementation within the mathematical classroom and how well their students perform in mathematics.

To further student mathematics achievement and to increase their mathematical achievement, a combination of teachers with high digital competence and the implementation of artefacts needs to exist. It is therefore vital for teachers to not only implement the digital artefacts but also possess the digital competence to utilize these artefacts to their full potential. The teachers need access to the digital artefacts in order to use them, but they also need the necessary education to navigate these artefacts. If teachers are given access to digital artefacts and are given the opportunity to increase their digital competence, they can provide their students with opportunities for higher mathematical achievement will increase.

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Appendix A

* 1. Do you understand that participating in this study is completely voluntary, that you will remain anonymous and that if you wish to end your participation the only thing you have to do is exit the page without turning the answers in?

- ◯ Yes

2. In what part of the world do you teach?

- ◯ Europe
- ◯ North America
- ◯ South America
- ◯ Africa
- ◯ Asia
- ◯ Australia

3. Have your students used ICT during their math lessons?

- ◯ Yes
- ◯ No
- ◯ Maybe

4. Are you comfortable with using ICT?

- ◯ Yes
- ◯ No
- ◯ Sometimes
- ◯ Most of the time

5. Out of all the lesson minutes in mathematics, how many in total do you estimate your students use ICT?

- ◯ Less than 10%
- ◯ Between 11 and 25%
- ◯ Between 26 and 50%
- ◯ Between 51 and 75%
- ◯ Between 76 and 90%
- ◯ More than 91%
- ◯ We have never used digital tools

6. Please elaborate upon how you (or why you don't) use ICT during your math lessons.

7. Do you perceive that the use of ICT impacts the students' mathematical abilities in any way?

- ◯ Yes
- ◯ No
- ◯ Unsure

8. In your own experience, how does the use of ICT affect the students' mathematical abilities?

- ◯ Positive
- ◯ Negative
- ◯ Unsure
- ◯ It doesn't affect their abilities

9. If you believe that the students' mathematical abilities are affected by the use of ICT in any way, please elaborate on how. Example: Their conceptual understanding has improved/it hasn't.

10. If you were given the opportunity, time and funding, would you like to incorporate more ICT into your math lessons?

- ◯ Yes
- ◯ No

Appendix B

Question 1	"yes"	Q11
Question 2	Europe	Q21
	North America	Q22
	Australia	Q23
	Asia	Q24
	Africa	Q25
Question 3	Yes	Q31
	No	Q32
Question 4	Maybe	Q33
	Yes	Q41
	No	Q42
	Sometimes	Q43
	Most of the time	Q44
Question 5	Less than 10%	Q51
	11-25%	Q52
	26-50%	Q53
	51-75%	Q54
	76-90%	Q55
	More than 91%	Q56
	Never	Q57
Question 7	Yes	Q71
	No	Q72
	Unsure	Q73
Question 8	Positive	Q81
	Negative	Q82
	Unsure	Q83
	Doesn't affect	Q84
Question 10	Yes	Q101
	No	Q102