Touch Features in Advancing Children’s Learning

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ABSTRACT

When examining the boundaries and issues imposed by the traditional ways of learning, questions about the role that new technologies can play in eliminating these boundaries easily emerge. This thesis intends to shed light onto these issues and better understand the effectiveness of using new technologies to overcome pupils’ problems in learning mathematics.

The empirical study conducted involves investigating how touch features available on tablets can enhance children’s learning. The aim is to study the significance of touch features existing on tablets in helping young pupils learn mathematical concepts like timetables. So, the general question underlying this research is “what functionalities of tablet technologies are effective to enhance children’s learning and what barriers are there to more effective use of them?”

Although previous research has studied the role of tablets on pupils’ learning, less attention has been directed towards the study of the effect of touch-input functionality in tablets to facilitate children’s learning. This thesis wants to contribute to the topic by analyzing how a particular functionality available, the touch-input functionality, can be utilized to foster learning.

For the purpose of our thesis project, a prototype is designed to introduce the concept of multiplication on a clock face. Then the prototype is tested with thirty primary school pupils selected from two primary schools in 6 days. Participants are divided into three groups using different methods to learn multiplication: traditional, PC without touch feature and touch-enabled device like tablets. We use different methods, such as pupil’s pre-test and post-test information, observations, interviews and questionnaires to develop the prototype, collect data and assess the pupils’ learning improvements. Both qualitative and quantitative methods have been used to analyze the collected data and interpret our experimental results. The qualitative approach is based on interpretive analysis methods, whereas the quantitative analysis is done in two steps, namely, some initial data analysis in the first step supported by more advanced statistical analysis, like ANOVA, Games-Howell test and analysis of average percentage of pupils’ progress in the next step.
The results of our analysis all confirm that pupils who use tablets to interact with our system show better results than those who use a computer mouse or learn in the traditional way. In other words, the results indicate that touch-enabled devices have the potential to facilitate pupils’ learning outcomes.

The present study is part of a growing body of research on the impact of mobile technologies on children’s learning. It is concluded that despite the existing concerns regarding applying tablet devices in school context, the positive effect of this technology dominate its drawbacks by integrating a well-defined plan in the educational world.

**Keywords:** touch input functionality, advancing children’s learning, tablet devices, mathematics learning, timetables, primary school pupils.
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1 INTRODUCTION

Technology can be a powerful mean to increase access to learning opportunities and promote a broader information society (Cummins & Sayers, 1995). With proper design and planning, technology can become capable of delivering education to students even in the smallest towns in the world (Carnoy & Rhoten, 2002). Mobile technology in particular with its low cost and widespread has great potential to provide access to digital educational resources (Zurita & Nussbaum, 2004). These mobile technologies also have the potential to be complementary resources in education, because they are highly manageable, simply distributable and affordable (Kim et al., 2011).

Today’s pupils are living in a digital world. Even at kindergarten, computers are being used as a tool in the teaching process. Klawe (1994) discusses that computer games could be considered as encouraging tools for those learners who may not have enough interest or confidence in learning. If computers can provide such opportunities for children and support them in their educational journey, the beneficial values that tablets can provide for children in the educational world should not be disregarded, as they are more intuitive, interactive and easier to use devices than computers. Most children know how to use tablets. Tablets are simple to use and can be integrated into school environment providing additional learning opportunities for students (of all ages) (Goodwin, 2012).

The engagement in preschool and primary school are very important milestones of children’s developmental process and crucial in their entrance in the academic life. At this stage, children’s engagement with media is critical, since they are developing new habits for learning and getting knowledge (Shuler, 2009). In this age range, the talented and ready-to-learn spirit of pupils creates a context in which any activity remains persistent and ineffaceable. When pupils enter the primary school, they are eager to learn new concepts. Thus, by using well-designed technologies we may support their enthusiasm and promote the development of mathematical skills in the early years of education, fostering the creation of a solid foundation and enable future learning achievements (Pitchford, 2015). Uzunboylu et al. (2011) suggest that current students have adopted new technologies like tablets in their daily activities and thus schools will need new pedagogical approaches that include digital technologies in the process of learning.
Evidence shows that students can get more engaged and interested in the lessons, if technologies like mobiles or tablets become an integral part of curriculum. Hwang and Chang (2011) show enhancement in students’ learning interest and learning attitude after applying mobile learning strategies in the learning process. By integrating technologies in the curriculum, teachers can provide collaborative learning opportunities for pupils. Collaborative learning makes learning more engaging and memorable. Several other studies show benefits of using mobile devices to enhance children’s learning. For example, the seminal work by Mike Sharples (Sharples, 2000) is particularly inspiring. As Kolb (2010) said:” Mobile devices bring the real world into the classroom, and they bring classroom into the real world”, mobile devices play critical role in children’s learning and they offer new opportunities in the educational world. Early evidence indicates that children can learn from well-designed educational apps (Chiong & Shuler, 2010). However, there are still many uncertainties about the influence of mobile devices, such as tablet computers and smart phones, on children’s knowledge and behavior (Kukulska-Hulme, 2007). One of the current challenges for educators nowadays is keeping pace with new technologies, because there are evidences showing the potential of new technologies in enhancing children’s learning (Clements & Sarama, 2002).

Although some results imply promising effects of using technologies in schools, not many studies have focused particularly on the effectiveness of using tablet computers and mobile devices in enhancing children’s learning of mathematics. Frequently, we see pupils complaining about learning mathematical concepts, like multiplication. For majority of pupils, learning math is a boring and difficult subject to understand (Mazzocco & Myers, 2003). This problem is seen from elementary school level. One of the reasons might be the teaching methods applied in schools. Teaching math in the traditional way might make pupils be passive learners just fighting to earn a passing grade without trying to learn the subject. One possible way to increase motivation and interest in this subject is to convince teachers to alter educational practices and introduce new technologies in the math sessions (Sollervall et al., 2012). The present work tries to address this strategy and study the impact of a tablet and mobile device-based environment for learning multiplication on pupils’ motivation, behavior and achievement. We introduce the topic of multiplication by considering a practical everyday task: telling the time. The idea is try to ground the learning of multiplication in an everyday meaningful task that children can easily relate to.
Few studies have been published where they have examined the use of touch-based devices in teaching mathematical concepts in the early years of primary school (Audi & Gouia-Zarrand (2013); Paek et al., (2013)). In order to better understand the potential benefits, which tablet technology features can provide for teaching, in this thesis work we consider how the touch feature available on tablets can be utilized to teach young children about telling the time and mathematical concepts like time tables. Here, we focus on pupils from age 7 to 9. To explore our idea, a mobile application was developed and a series of evaluation studies using individual interviews and questionnaires were conducted to see if young children’s learning can be enhanced through the use of the touch feature of tablets.

1.1 Aims and Objectives

One important issue that we need to address is understanding how different interactive features specific to tablets can be used in the learning contexts. One of these features is touch screen functionality. In order to gain some understanding regarding the inclusion of the touch feature and its significant role in facilitating children’s learning, our research aims are:

- To study the role of tablet computers in supporting learning experiences of children in mathematical concepts like time tables.
- To investigate how the touch features available on tablets is helpful to teach young children about time.
- To illustrate that in spite of the belief of most parents and teachers, mobile devices are not just a source of fun and entertainment, but they can have significant role to enhance children’s learning and help children to learn essential skills needed for success.
- To examine the opportunities and challenges that tablets might have for children’s learning.
- To exemplify teaching and learning with tablets.
- To study how tablets can motivate the way youngsters learn.
1.2 Thesis outline

The thesis is structured in the following way:

In chapter 2, we survey the relevant works that has been published in the field of mobile learning and the effects of technology in children’s education. To have a clearer view, this section is divided into three subsections. In chapter 3, we show different phases of our project using the methodological framework introduced by Scaife et al., (1997). In this chapter, we first provide a brief overview of various phases of our work, show what different methods have been applied in each phase and introduce our informants and contributors in each phase. We then give a brief explanation for each phase. Chapter 4 provides specific details of our research question that should be answered at the end of the study. We also give an explanation about the participants of our project and the experimental conditions of our research in which our study was conducted. In chapter 5, we describe the technical approach of our prototype and the motivating factors behind the selection of the technical platform. Furthermore, we illustrate an overall view of our system and describe the architectural pattern of the system in a sequence diagram. We also describe how users interact with our system in a usage scenario. Chapter 6 is emphasized on the evaluation session of our project. Providing some detail about the evaluation procedure and evaluation methods are also in the focus of this section. Chapter 7 is about data analysis and discussion of the results. In this chapter, we mainly talk about data analysis methods. Data analysis is an important stage in our project which helps us discover useful information about our data. This chapter is divided into two main parts. The first part is mainly focused on an initial analysis of our data. In the second part, we mostly focus on testing differences between experimental conditions. Chapter 8 is titled as “Discussion”. In this chapter, we examine our results in relation to our research questions. We discuss the results of our study and provide explanations for our findings. Chapter 9 is the conclusion of our research, where we summarize the content and purpose of our work. In this chapter, we provide the final word of our research. The final chapter of this report outlines the limitations of our study. Like any research, our work have had some limitations which we talk about in chapter 10.
2 REVIEW OF LITERATURE

In this section, we will present an outline of the relevant works associated with the use of technology by children and its impact on teaching and learning. As shown in figure 1, the structure of this section is as follows: first, we begin with a brief introduction on technology usage in schools and express using technology in the process of learning in schools, then we will be specifically focused on research related to deploying mobile devices and apps in school environment, defined as mobile learning. Finally, we will review the current research conducted on the use of tablets for teaching mathematics in elementary school classes.

Figure 1- The structure of Literature Review
2.1 Technology Usage in Schools

Digital technologies play a significant role in students’ lives as they like to use multimedia and digital tools in all aspects of daily life. This may cause some issues for teachers to communicate and interact with the new generation of students and keep them focused on the lessons. Since computers, tablets and other digital devices are multi-purpose, so they can be used as non-educational source of fun as well. Therefore, students might get tempted to do other things more fun and attractive than school works. Thus, teachers should use suitable communication methods and choose proper ways of teaching. Teachers can use digital technologies in the classroom to deliver educational programs. For example, personal learning devices (PLDs), which include students’ personal digital devices, like iPod, iPads, tablet PCs and smartphones, can be considered and used. Students could apply PLDs as an essential part of their learning experience. Liu et al., (2009) indicate that PLDs promote students participation and collaboration in the classroom activities. Appropriate use of PLDs in classroom can make a change in the educational environment and increase the quality of education as well as students’ performance in schools (Yoon et al., 2013). Today, the importance of using technology in school context to some extent is clear for everyone. However, the responsibility of applying technology in classroom and making proper use of it is on teachers (Yoon et al., 2013).

There has been considerable investment to bring technology to school and many successes have been achieved in this way. For instance, Liu et al., (2006) indicated that students’ knowledge improved after engaging them in a computer-enhanced problem-based learning environment. As a successful experience of applying technology in school, we can point out the work done by Yang (2009). He presented a case in which technologies were used as learning tools in an oral history project. This research illustrated that students gained many benefits from applying technology in classroom, including: teamwork, learning interviewing techniques, obtaining knowledge in tackling research project, enhancing project solving skills, enabling students to view historical issues from a variety points of view and improving students’ sense of confidence and responsibility (Yang, 2009). A research conducted by Tamim et al., (2011) has also confirmed the positive impact of technology on students’ achievement. The purpose of their study was to collect forty years of researches together to answer the question: “what is the effect of using computer technology in classroom, as
compared to no technology, to support teaching and learning?” They conducted a second-order meta-analysis to summarize the findings of many other meta-analyses in relation to the role of technology on students’ learning performance. Their study results was in favor of applying technology in formal academic context over the traditional technology free classrooms and they revealed that technology has significant positive small to moderate effect size on the experimental group. Lim et al., (2013) addressed two main gaps of technology use in the educational world and the causes of the gaps. One of the gaps was the usage gap, namely the extent to which students use technology in school. Despite the widespread use of technology outside school, the use of technology at school is much lower. The second gap was about the outcome: outcomes achieved for in-school activities is far smaller than the outcomes of non-educational activities outside school. Lim et al., (2013) in addition expressed that activities of students in their everyday lives had become disunited from the teaching and learning activities in schools. This may change students’ attitudes toward school curriculum and make them discouraged from school activities. Law et al., (2008) argued that technology had been modifying the teaching and learning process in classroom.

In spite of the positive impacts of modern technologies on other industries (e.g. cost savings and enhanced performance), schools have not gained much benefits in this regard. One of the reasons for the gap between technology development and use of technology in schools is the deficiency of technology planning (Lim et al., 2013). In order to make the most benefit of integrating technology in education, schools should have a technology plan that describes their objectives, expectations and activities. We cannot ignore the speed with which technology is growing. Nowadays, teachers and educational authorities are working with a generation of students who are growing with technology as an integral part of their lives. Therefore, the question for school authorities is not any more whether to use technology in school, rather they should consider the question about how to use technology within classroom activities. To increase productivity and potential advantages of technology in the learning process, schools should create a school-based technology plan (Lim et al., 2013).

Dede (2010) mentions ICT (Information and Communications Technology) as a fundamental skill of twenty-first century that affects different aspects of people’s lives, such as thinking, learning and collaboration. Thus, schools should think of modifying the traditional approach in the teaching process and integrating new technologies in the
educational settings. It is important to note that studies emphasize that teachers’ role in transition from traditional to new approach should not be neglected, as they are central agents in integrating technology in classrooms (Davidsen & Vanderlinde, 2014). Ottestad (2010) stated that ‘teachers play a crucial role in developing schools into modern technology-enhanced institutions’.

Evidence illustrates that technology could be applied in the educational settings in order to maximize learning outcome of students (Liu, 2016). Liu (2016) studied technology integration in elementary classroom with the aim to enhance learning. Thirty first student teachers participated in their study for about 8 weeks. The first and top reason for participants in the Liu’s study to integrate technology in their education was to attract students’ attention and motivation and make the lessons more entertaining and engaging. Getting organized in planning and teaching, encouraging students’ participations in teaching with rewards and addressing the needs of individual students are other reasons for participants in Liu’s study to use technology in teaching. Despite the reasons that have been counted by Liu (2016) and other researchers like Usun (2003) on applying technology in schools, there are still uncertainties about deploying technology in classroom.

2.2 Mobile Learning

The revolution of mobile technology has affected people's lives at all ages (Chiong & Shuler, 2010). Considerable research has been done in the field of mobile learning over the past years and mobile learning projects have developed a set of significant tasks in schools, workshops, museums, etc. around the world (Sharples, 2007). However, mobile learning is still considered a young research field.

All children love running around and playing, but learning is also an important part of children’s development. Currently, with the incredible growth of mobile devices children show interests in these technologies. Although teachers nowadays may still prefer the traditional teacher-led classrooms, which uses papers and pens, students prefer screens to papers and keyboards to pen or pencil. For example, Yoon et al., (2013) indicate that teachers encounter problems and concerns in interacting with students in classrooms, because teachers
are more familiar with paper-based context, whereas students who are surrounded by different multimedia and digital devices, are more interested in screen-based context.

In this section, we will review some of the projects that have shaped research and development of mobile learning. One of the early projects in mobile learning was HandLeR (Handheld Learning Resource) from the University of Birmingham (Sharples, 2000; Sharples et al., 2002). The aim of this project was to facilitate people in their personal learning lifetime. The project was focused on developing a HandLeR device to enable children to learn, share and organize lessons and also communicate with other learners and teachers from any location throughout a lifetime. Handheld devices contain any portable device that can be carried out in hand. The HandLeR project began with analyzing the complex interaction between people and computer-based technology and then transformed this analysis into possible socio-technical systems. Sharples et al., (2002) illustrated in their project that Handheld devices introduced a new generation of portable learning resources. MOBIlearn was another European-led research that involved 24 partners from academia and industry in ten countries. The focus of the project was to develop and support learning outside the classroom, including learning in museums. The M-Learning project was another project which like MOBIlearn, was funded by the European Fifth Framework programmer, but its aims were to help young adults aged 16 to 24, who were disaffected learners and had not succeeded in the education system. The UK Learning and Skills Development Agency (LSDA) was the coordinator of the project. The participants were the universities and commercial companies from UK, Italy and Sweden (Kukulska-Hulme et al., 2009). In this project, participants had the opportunity to get access to learning materials from different types of mobile devices, plus web and TV. As an example of the M-Learning application, we can mention a mobile game, which enables learner drivers to exercise driving theory questions. The project illustrated that mobile learning is not just a tool for teaching material, but it could empower student’s creativity, collaboration and communication.

If we come to the recent mobile learning projects, we encounter a wide range of projects illustrate learning across different educational contexts (schools, universities, museums, informal learning, professional development and workplace settings), with different target groups (including children, adults, and professionals). Learning2Go (Faux et al., 2006) and ENLACE (Verdejo et al., 2007) are some of the school-based mobile learning projects. In
a recent work, Su and Cheng (2013) have developed a mobile learning environment based on MILS (Mobile Insect Learning System) gamified learning activity. The aim of their work is to investigate how different learning conditions can influence student in botanical learning process in an outdoor educational environment. The participants of this study included three classes of fourth grade students (aged 10-11) in an elementary school in Taiwan (Su & Cheng, 2013). Participants were randomly divided into three groups. Different teaching methods and learning conditions were assigned for each group. The study showed that students’ learning achievement is influenced by their characteristics (such as gender, subject interests and prior experience). They concluded that the learning performance of male students is higher than females, and experienced students have higher performance than non-experienced students.

Most of the researches imply that it is an important issue to place students in a series of designed lessons that combine both real-world and digital-world learning resources via the use of mobile and wireless communication technologies (Chu et al., 2010). Bidin and Ziden (2013) have presented a historical outline of mobile learning concept. In this study, they have tried to enumerate several factors that influence mobile learning in education. Some of these factors are fun, flexible learning and interactive learning. The need for well-designed learning support in order to improve students’ learning achievements led Hwang and Chang (2011) to propose a formative assessment-based approach in a mobile learning environment. Based on their research, this proposed approach besides attracting students’ attention and interest, improves their learning outcomes. So, it is an important issue to develop methodologies or tools to assist students to gain knowledge in a mobile learning environment. Sarrab et al., (2016) have proposed a model that describes the technical quality aspects of mobile learning products. The aim of their work is to identify the technical aspects of mobile learning services that are helpful when developing mobile applications in education environments.

One of the important parts that researchers have emphasized in mobile learning is improving students’ learning achievements with mobile technologies. For instance, Elfkey and Masadeh (2016) proposed an approach to study the influence of mobile learning on students’ achievements in Najran University. The study consisted of 50 students who were divided into two groups: experimental group and control group. The participants were registered in a course called “Strategies of Teaching and Learning”. The course content was delivered in two ways: students in the experimental group used a soft copy of the course content uploaded on
the university blackboard system. Students in the control group received a hardcopy of the course content by hand. The results of the study revealed that mobile learning eliminates time and place constraints, therefore they have positive impact on students’ academic achievements and English conversational skills comparing to the traditional teaching methods. The growth of mobile technologies has encouraged an increasing number of studies in relation to mobile learning, which enables students to learn via mobile devices without being restricted by space and time. Baran (2014) has conducted a review of 37 articles regarding mobile learning and teacher education. This review revealed the growing number of articles published in the field of mobile learning. This study showed that teachers play a significant role in integrating mobile devices into educational world, since they are the best resources in addressing students’ learning needs from different perspectives. Nevertheless, Baran (2014) mentioned that lack of teacher support and training is one of the topics in mobile learning that has not been explored widely. This means that despite the rapid use of mobile technologies in school context, there has been few research done regarding preparing and advising teachers to integrate mobile technologies into their classroom.

Progresses in mobile technologies are showing enormous educational potential for today’s generation (Shuler, 2009). Van’t Hooft (2013) believes that applying mobile learning in a meaningful and effective way in the educational world requires making changes in education. In the report, Pockets of Potential (Shuler, 2009) undertaken by the Joan Ganz Cooney Center at Sesame Workshop, researchers try to illustrate how mobile technologies such as cell phones and iPod devices could be used for learning. There, they have mostly focused on promoting children’s informal learning through apps made available for use by children during their leisure or out-of-school time. Shuler (2009a) published a mini-study, called iLearn, which expresses the significant impact of mobile devices in the educational settings for children. Although this study showed the considerable benefits of mobile technologies on children’s development, but the reason for the popularity of mobile technologies and the extent to which they can be used in the learning process is not exactly clear. In the other work, Chiong and Shuler (2010) pointed out the need to understand: how to use apps in preschool and primary school settings or how might app use differ for children in play versus learning situations. They have presented the results of three studies conducted by: PBS Kids Raising Readers and Rockman et al, Cooney Center and Seasame Workshop, and
Cooney Center and Hotspex. The results of the studies reported here demonstrated that mobile devices are being used by children at home and they perhaps will be considered as a part of children’s learning in classroom from 2015.

While there are a number of examples of the use of mobile devices for communication (such as Mayisela (2013)), few examples currently exist on how they might be used to engage students in meaningful tasks at school, especially in pre-school and primary years. There are still many questions to be answered in the research area of mobile learning. Though there have been lots of researches in the field of mobile learning, few of them specially focused on student perception in preschool and primary years. Most of these researches have their focus on informal learning.

2.2.1 Effective factors and issues in learning with mobile devices

Mobile devices are increasingly being used in different parts of people’s lives. This fact together with the possible opportunities that these devices can provide in learning suggest the need to understand better which factors are effective when it comes to mobile learning. There are a number of factors that might influence learning with mobile devices. Bidin and Ziden (2013) discuss some corresponding influential factors, which are summarized in a diagram shown in figure 2.
As seen from figure 2, the effective factors are divided into three main groups:

- Features of the devices: Distinctive characteristics of mobile devices, which can be divided in some point of view into three categories:
  - Usability, which refers to the characteristics like compact, lightweight and portable (Cavus & Ibrahim, 2009). From the usability point of view, learners are not restricted to a classroom with limited learning materials and the learning procedure can be accomplished at anytime and anywhere. Therefore, the usability feature provides flexible learning process.
  - Technical, which may concern features like availability, maintainability and flexibility of mobile applications.
  - Functional, which may refer to aspects like access to instant and spontaneous information and continuity. These aspects allow learners to quickly find certain
information or answers to specific questions in a short period of time from anywhere they like. In other words, the mobile devices provide a continuous learning opportunity which does not necessarily restrict with time and location.

- **User’s expectations:** Learners intentionally or unintentionally have some expectations in a learning process and if they are satisfied, the learners will be more motivated and enthusiastic. Bidin and Ziden (2013) list the following aspects, which to some extent intersect user’s expectations and should be considered in a mobile learning process:
  - Ownership
  - Privacy
  - Self-Regulated learning (Control of the learning)
  - Flexible learning
  - Life-long learning
  - Fun

- **Pedagogical advantage:** Some learning approaches, which correspond to pedagogical advantages of using mobile devices in a learning process, are as follows (Bidin & Ziden (2013)):
  - Collaborative learning
  - Blended learning
  - Interactive learning
  - Experiential learning (Learning in context)
  - Problem-based learning

Besides the above categories of effective factors in learning with mobile devices, which do not also look completely separate and independent from each other, it is important to note that there are other factors that are not ineffective in learning with mobile devices and indeed they become essential at some point. For instance, one of the factors is the quality of mobile adoption in school context by instructors and students. To achieve a reasonable quality, instructors and students should be familiar and have some general knowledge about mobile technology and applications. Another factor is monitoring students’ learning activities in the classroom. Teachers should guide and conduct students to be successful during the academic year. To achieve this goal, they should define the rules for students at the beginning of the academic year and monitor students in achieving them.
As using mobile devices in the learning process can provide many opportunities for students, several issues and challenges may also appear. Similar to the influential factors above, Bidin and Ziden (2013) classify the main issues and challenges in mobile learning in three groups, which are illustrated in figure 3.

- **Features of mobile devices**
  - Small screen size is the main issue that Bidin and Ziden, (2013) mention in their research. The cognitive and ergonomic issue and lack of consistency design scheme are other issues that have been mentioned. These issues relate to the usability of mobile devices.
  - Bidin and Ziden, (2013) emphasize several issues from the technical point of view for mobile devices. Connectivity issue, low battery life, accessibility, security issues, cyber-crimes and issue of storage are among these issues.

- **Users’ expectations**
  - Deploying mobile devices in the learning process brings about some costs for schools. Besides the cost of the devices itself, deploying mobile learning systems forces more costs on schools.
  - Before starting the teaching and learning strategies, schools should make clear their policies regarding the social media. Since teachers might plan their teaching strategies in a way that requires the use of social media, such as Facebook, without being aware of the school policies regarding such sites, which might be blockage. So this might cause frustration and discouragement among teachers and students.
  - The advent of newer devices can make the former devices obsolescence. New kinds of devices might pop up only few weeks after students master mobile devices.
2.3 Tablet Usage in Schools

It is not exaggeration, if we mention tablets as cool mobile devices that have made their way into different aspects of people’s lives. IPad-centric education is now one of the cool topics that has caught many attention in research (Couse & Chen, 2010; Hu, 2011; Brown-Martin, 2010). Using tablets and other mobile technologies in classroom will help students to learn in a more interactive and collaborative way. “Mobility, connectedness, communication, social
networks and collaboration” are some features of iPad that turns it into a great learning tool (Culén & Gasparini, 2012).

Cuban stated that “iPads are marvelous tools to engage kids, but then the novelty wears off and you get into hard-core issues of teaching and learning” (Hu, 2011). The work done by Culén and Gasparini (2012) confirms this statement. They studied the role of iPad in the learning process of tween population (children aged 8-12 years old). Their research involved two case studies, which were part of larger pilot studies with the aim of introducing the iPad to two Norwegian elementary schools. The first case was about creating an iPad app by children for learning to develop media product. In this part, children developed a weekly newsletter using words, pictures and videos. The second case was about a storytelling app, Puppet Pals, which motivates children to use the app to learn about storytelling. The participants of the study were students from two elementary school in Norway. One of the schools was in the provincial area of the country and the second school was an urban school. The methods applied in this study include observation, interviews and participating in students’ presentation sessions. This study illustrated that the opinions and experiences of children and their teachers regarding the described activities and the success of the study were different. This was because teachers and students participating in this research had different criteria for defining success. From the students’ points of view, the project was truly successful, since their criteria of the project success were related to the amount of fun and enjoyment that they had in using the iPad and trying something new. Whereas, teachers did not find the project to be successful, since their key criterion was the learning outcome. Teachers found the learning outcome of the project weaker than the traditional learning style.

Benloch-Dualde et al., (2010) have proposed an approach that uses mobile tablet technology to design interactive classrooms. This approach supports students’ collaboration via combining learning techniques with tablet technology. The proposed approach was built upon several steps: providing recommendations to prepare lectures and exercises materials using technology, getting students engaged with lessons by designing in-class activities, providing the opportunity of collaborative learning, and designing different learning activities such as exercises, problem sets and quizzes to be solved using tablet PCs in the classroom. The result of this experiment shows that this approach improves students’ motivation and performance. It also increases students’ self-confidence in the learning process. Similarly,
Higgins et al., (2011) and Higgins et al., (2012) suggest that children are more interested to work with multi-touch tablets than traditional paper-based tasks.

Even though technologies are considered to be a source of fun and entertainment, there have been many success stories that show the significant potential of new technologies in supporting students’ learning. For instance, as a successful experience of applying technology in school, we can mention the research by Audi and Gouia-Zarrand (2013). The aim of their study was to explore the learning outcomes of applying iPads in teaching math courses. The study analyzed the use of iPads in teaching a first year mathematics course in American University of Sharjah (AUS). The effectiveness of the approach was tested through a pilot study, in which 17 students were participating. Different materials about trigonometry were delivered to students by instructor using iPad. To observe students’ progress throughout the study, the instructor delivered some questions to the students during the class, which should have been answered in 5 minutes. Their results demonstrated that integrating tablet PCs, especially iPads, in math courses have positive impact on students’ engagement and concentration in the class and also makes the class more dynamic by increasing the interaction between teachers and students.

Study by Law et al., (2008) is another example of successful stories. This study aimed to provide some suggestions regarding applying mobile devices in teaching and learning, and also give advice for effective use of mobile devices in school context in NSW Department of Education and Communities (DEC) schools. Besides, they provided information for planning and implementing iPads in classroom environments in NSW DEC primary school. Their results were related to two side areas:

1. Teaching and learning implications
2. Technical and logistical considerations

Their findings indicated that iPads improve students’ engagement and motivation and have positive impact on their collaboration in schools.

Karsenti and Fievez (2013) also carried out a survey that highlighted both advantages and disadvantages of using tablet in primary and high schools in Quebec, Canada. The aim of their study was to demonstrate that besides the potential that touch-based devices bring to education, they impose several challenges into education as well. Participants of the study were 6,057 students (from grade 6 to 10) and 302 teachers from 18 schools in Canada. They
summarized the benefits and challenges of using iPads in classroom from both students and teachers points of views. They also illustrated the frequency of their responses, where each student was able to select more than one response. Figure (4), shows students’ responses to the questions regarding the benefits of using iPad in the classroom. More than half of the students considered portability as the main benefit. Next places were allocated to access to the information, the quality of student’s presentations, creativity and motivation. Improved reading experience came next. The less number of responses were allocated to making notes on documents, work organization, collaboration with other students and teachers and IT skills. The lowest place in the table belonged to working at one’s own pace.

![Figure 4- Main benefits of using the iPad in class, as perceived by students (reproduced from Karsenti & Fievez, 2013)](image)

They also asked teachers about the benefits of applying iPads in classroom. Some of their responses were in the same line as students. Access to the information and the portability of device were the most often mentioned benefits. Greater collaboration, possibility of working
at one’s own pace and easier work organization were in the next places in the table. Higher student motivation and quality of teacher’s and student’s presentations came next. Some other mentioned benefits were foster creativity, teachers cut down on paper, variety of resources, making notes on pdf files and improved reading experiences. The less cited benefits were teachers and students develop IT skills (see figure 5).

![Figure 5- Main benefits of using the iPad in class, as perceived by teachers (reproduced from Karsenti & Fievez (2013))](image)

Students and teachers were also asked to response the questions regarding the challenges involved in using iPads in classroom. As shown in figure (6), both groups, students and teachers, believed that the top negative aspects of iPads is that they are a source of distraction
for students. Form teachers’ as well as students’ points of views the challenges looked almost the same, difficulty writing with iPad and managing school work were also mentioned as the negative impacts of iPad. Textbooks was the other problem and challenge stated by both teachers and students. The minimum number of students and teachers mentioned that iPads might reduce the academic performance of students.

The statistics done by Karsenti and Fievez (2013) about the overall satisfaction of students and teachers with using iPad in classroom is shown in figure (7). Their results indicated that students are more satisfied than teachers with using iPads in classroom.
There are also other empirical evidence that discuss positive impacts of tablet technology. During the past few years, a number of studies have been carried out on the use of tablets in schools. Below, we list to some extent the corresponding research findings and publications of the past years:

- Shuler (2012) suggests the potential of apps in supporting learning activities.
- Goodwin (2012) considers the use of iPads in classroom environments and their impact on teaching and learning. He indicates that tablets increase students’ engagement and motivation and improve their learning outcomes.
- Applying mobile devices in the learning process enables students to experience innovative learning practices. In this way, students are not limited only in the classroom environment, but the learning could be extended beyond the classroom (Rikala, 2012).
Churchill et al., (2012) suggest that iPads have the potential to generate flexible and collaborative learning environments, however they state that this is not sufficient to assert the influence of tablets on learning. They believe that for incorporating tablets in the educational settings, teachers’ perception on how this technology must be used should not be disregarded. When studying the effect of tablet in education, focusing only on students’ feedback on the use of tablets is not sufficient and in fact teachers’ attitude toward using these technologies in classroom play a significant role in gaining good results.

Zimmerman and Howard (2013) confirm that in order to use tablets in classroom, teachers should have an efficient and practical plan.

Dhir et al., (2013) conducted a review of literature in the field of iPad’s role in education and listed a number of benefits of using iPads in learning, some of which are: ease of use, opportunity for ‘anytime anywhere learning’, interactive learning, large number of educational apps and reducing teachers’ workload.

Paek et al., (2013) illustrate the potential of tablets in advancing children’s learning of multiplication. Their results indicate that students’ math learning could be facilitated and improved by the touch potential of tablets. To arrive at this conclusion, the concept of multiplication was introduced by designing a Puzzle Block game. Then two different platforms, tablets and laptop computers, were used to examine the impact of different physical interactions on students’ learning of multiplication.

Riconscente (2013) conducted a study on the iPad app “Motion Math” that helps student’s gain skill and better understanding of Fraction. The results of this study show evidence about improvement in participants’ fraction knowledge. The research mostly study the role of tablets in enhancing children’s learning without considering teachers’ perception of how these technologies could be used in education.


Pitchford (2015) argues that tablet technologies are appropriate for improving students’ early years of mathematical skills, if the software and its content is well-
suited in the school curriculum. He illustrates the effectiveness of tablets in supporting early mathematical skills of primary school children in Malawi as a low-income country.

- Davidsen and Vanderlinde (2016) studied teachers’ and children’s attitude toward using touchscreens in classroom for collaborative learning. They present and discuss three cases in primary schools as target group, which show children’s engagement and collaboration around touchscreens with the help of teachers. They emphasized the importance of collaboration as a necessary skill for educational settings in twenty-first century.

- Outhwaite et al., (2017) conclude the same results as (Pitchford, 2015), but in a high-income country such as UK. They evaluate the impact of applying hand-held tablets in the UK educational settings for children aged 4-7 years old. Their results approve the positive impacts of tablet integration into early primary schools in supporting early mathematical skills. They demonstrate that even children with low memory skills could benefit from tablet-based math classes.

We should have in mind that besides all the opportunities and advantages that using tablets bring to students and teachers, like any other changes, it has its own disadvantages as well. There are publications, where some of these disadvantages are discussed. For example, Lim et al., (2011) address that using tablets and other similar types of technologies may reduce social interaction and thus increase the likelihood of social isolation among students. Another issue is that tablets may cause distraction among students and instead of focusing on education, students may be tempted to do sundry works (Clark & Luckin, 2013). In this thesis work we are mostly interested in positive effects of using tablet technology on advancing educational approaches.

Although a number of studies have shown positive effects of tablets on children’s math learning compared to the traditional format of teacher-centered classes, the potential of tablet-based classroom is still ambiguous and needs more explorations to establish in a more clear way the putative benefits of these technologies. Little research has examined the relation between learning and tablet interaction. There are relatively few research studies on specific teaching methods for multiplication using tablets in elementary mathematics classes. Therefore, there needs to be more research on the impact of tablet usage in elementary school
classes. The present study aims to determine whether tablet interactions could help children increase their multiplication knowledge. We are mostly interested in studying the significance of touch feature existing on tablets in a sense whether this feature available on tablets helps young students’ learning. In the following sections, we discuss the experiment in more details.
3 METHODOLOGICAL FRAMEWORK

Researchers suggest that children should be involved in the designing process of interactive learning environments (Druin, 2002). Children are aware of some aspects of learning/teaching process that we are not (Scaife et al., 1997). They view different aspects of learning and teaching from within the scope of the learning process rather than beyond it. For instance, they can tell the design team what features are fun for them or what factors encourages learning. So, children could be considered as one of the main aware source of learning practices. However, it is not clear what role they can have in the designing team and what is their level of contribution regarding the design process (Scaife et al., 1997). Scaife et al., (1997) state that applying a child-centered framework in the app design process could help the design team use children’s experience to identify effective learning methods, motivating elements and key factors in increasing students’ engagement. Nevertheless, the role of teachers and educational stakeholders cannot be disregarded here, since they are good sources for informing the design team about the students’ learning goals.

Scaife et al., (1997) introduce a methodological framework that shows how different informants could be involved in the designing process and what ideas they can provide at each stage of the project. Following this methodological framework, table 1 illustrates the different phases of our project with brief overviews of various methods and contributors.

<table>
<thead>
<tr>
<th>Phase of Design</th>
<th>Informant/Design Team Contributor</th>
<th>Input</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1- Define domain and problems</td>
<td>Researcher</td>
<td>-Read existing literature in the same problem domain</td>
<td>-Literature review;</td>
</tr>
<tr>
<td></td>
<td>Teacher</td>
<td>-Specify learning aims; -Identify difficulties in teaching timetables and multiplication;</td>
<td>-Teacher interviews;</td>
</tr>
<tr>
<td></td>
<td>Children</td>
<td>-Explain difficulties with learning clock reading; -Explain difficulties with learning timetables;</td>
<td>-Talk with children in school context;</td>
</tr>
<tr>
<td>Phase 2- Translation of specification</td>
<td>Researcher</td>
<td>-Compare conventional &amp; multimedia materials in teaching mathematics; -Explore and define scope of interactivity</td>
<td>-Reading, collecting and analyzing information</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Software/graphic designer</td>
<td>-Turn problems identified in phase 1 into particular design features;</td>
<td>Storyboarding, sketching;</td>
</tr>
<tr>
<td>Phase 3- Design low-tech materials &amp; test</td>
<td>Researcher</td>
<td>-Research and gather information about designing applications for children; -Get initial ideas about designing interactive learning environments;</td>
<td>Reading, collecting and analyzing information;</td>
</tr>
<tr>
<td></td>
<td>Software/graphic designer</td>
<td>-Test validity of design assumptions; -Build main functions of the system;</td>
<td>Make low-tech materials;</td>
</tr>
<tr>
<td></td>
<td>Teacher</td>
<td>Test the functionality of the preliminary prototype</td>
<td>Try out the prototype and give feedback for improvements</td>
</tr>
<tr>
<td>Phase 4- Design and test hi-tech materials</td>
<td>Software/graphic designer</td>
<td>-Using feedback and results from previous phase to validate design aims;</td>
<td>Make the prototype using html5, jQuery, … ;</td>
</tr>
<tr>
<td></td>
<td>Teachers</td>
<td>-Verify the usability and effectiveness of the developed prototype;</td>
<td>Try out the prototype; give feedback about the functionality and usability of it;</td>
</tr>
<tr>
<td></td>
<td>Children</td>
<td>-Try out the prototype to get familiar with different parts of the prototype;</td>
<td>Running introductory sessions;</td>
</tr>
<tr>
<td>Phase 5- Test and evaluate</td>
<td>Children</td>
<td>-Evaluate interactivity and touch feature of the prototype;</td>
<td>Use the prototype as a learning app;</td>
</tr>
</tbody>
</table>
In the following, we shall have a brief explanation of each phase:

### 3.1 Phase 1: Define domain and problem

The focus of this phase is on identifying learning goals of mathematical concepts like multiplication. Treating children and teachers as informants at this stage helps us to identify the advantages and disadvantages of current teaching methods. To achieve the aim of this phase, besides reviewing the literature, we organize some meetings with teachers at school. We ask teachers about their methods of teaching the mathematical concepts of our concern, issues that they see problematic and solutions that they might have in mind (see Appendix C). Discussions with children in this phase are focused on their experience of being taught multiplication and timetables and also difficulties that they encounter in this regard. These meetings help us to get practical ideas about the functionalities of our prototype. As the outcome of this phase, we create a list the content of which is problems that children encounter when learning multiplication and clock reading (see Appendix D). One of the main problems identified in this phase is poor instruction and insufficient teaching resources.
3.2 Phase 2: Translation of specification

Considering the problems identified in phase 1, in phase 2 we try to classify and compare different materials that are being used in teaching multiplications. We examine users’ (pupils and teachers) needs and expectations to create a requirement specification document, which is served as a guideline for designing our prototype. Because of the time limit, we are not able to fulfill all the requirements of our users. So, we prioritize the requirements and focus on those that are more critical and have high priority in our project. Turning the recognized requirements and the most important needs of our users into possible design features is one of the objectives at this stage.

3.3 Phase 3: Design low-tech materials and test

After gathering some information, obtaining a little background about our study and classifying the aims of our work in the previous phases, in this phase we try to collect some facts about designing interactive environments for children. Having all these information in mind, we start to convert the sketches into a functional prototype. So, we build the preliminary prototype of our system with its core functionalities based on the requirements identified in the previous stages. During this preliminary design, we frequently ask our stakeholders (pupils and teachers) to supervise our work and see if the app is being developed based on their requirements. We ask teachers and pupils to try out the preliminary prototype and give us their feedbacks and comments to apply them in the next stage for improved functional prototype (see Appendix C).

3.4 Phase 4: Design and test hi-tech materials

We apply the feedback from the prior stage to develop the finalized prototype. After developing the fully functional prototype, we test it again with teachers to verify the functionality of our prototype. The final refinement is done and the prototype is ready to be used in the evaluation sessions. For children to get familiar with our finalized prototype, we run an introductory session focused on how our system works. At the introductory session, we give some direct instructions about the prototype. The purpose of the introductory session is to
allow children gain enough skills to use our prototype and get ready for the next sessions. The technical approach used for designing phases 3 and 4 is discussed in chapter 5.

3.5 Phase 5: Test and evaluate the prototype

In this phase, we first hold a coordination meeting with teachers to provide them with details about the evaluation session of our prototype. Having this meeting is necessary, because teachers plan pupils’ curriculum from the beginning of the academic year and we have to ensure that we are not ruining their plan. Then, we run the evaluation sessions to assess the improvements of children’s learning of multiplication by using our prototype. We apply different methods to conduct the evaluation process of our research, such as: observation, interviews and questionnaires. During the session, pupils are using the prototype to learn multiplication, while a teacher is supervising them. Teachers grade pupils and assess their knowledge of multiplication before and after using the prototype. More detailed discussion about evaluation methods and procedure will be provided later in chapter 6.

3.6 Phase 6: Evaluate the results and analyze data

The main focus of this phase is to evaluate and analyze the data collected in the previous stages. To achieve the aim of this phase, we use a number of methods, like interpretive analysis methods, ANOVA, Games-Howell test, etc. to do statistical analysis on our collected data. In addition, we interview teachers about their overall experiences and ask them to fill some questionnaires. In chapter 7, more details will be provided regarding the statistical methods, interviews and questionnaires.
4 RESEARCH QUESTION AND EXPERIMENTAL CONDITIONS

4.1 Research Question

As mentioned previously, our main research question in this project is to clarify “if the touch feature available on tablets is beneficial to teach young children about time and related mathematical concepts like time tables?” There are other questions that might come up while we are investigating our main research question, which are:

- **RQ1** - What do teachers think are effective uses of mobile technologies to enhance children’s learning and what barriers are there to more effective use of them?
- **RQ2** - What particular features of tablets do the teachers think can be more engaging for children and facilitate the learning process?
- **RQ3** - In which ways can the utilization of the interactive features of touch-enabled devices be used to enhance learning content (for example, graphics) to foster the learning of pupils and positively change the way children experience the learning?
- **RQ4** - What opportunities these technologies may provide in the educational world and are these opportunities outweighing the challenges of using mobile devices in school?

So, it is hypothesized that using new mobile technologies with touch features, like tablets, positively enhance children’s learning of mathematical concepts, comparing to the traditional approaches in teaching. The following formal hypothesis is developed for our experiment:

**Hypothesis:** Children using touch-enabled tablets and corresponding interactive graphics to learn multiplication tables will have better scores on a multiplication test than children taught with regular laptops or without ICT devices.

4.2 Experimental Conditions

To find some answers for our research questions and investigate the above hypothesis, we define and conduct a research experiment. The experiment took place in Firoozabad, Fars,
Iran. In Iran, there are two types of schools: public and private and all the schools are single-sex. We selected two primary schools, one girls’ school and one boys’ school in order to have both female and male pupils participating in our research.

**Overview of school 1:**
At the time of our case study, the school had 160 pupils from grade 1 to 5. The average number of pupils in each class was 32.

**Overview of school 2:**
At the time of our case study, the school had 153 pupils from grade 1 to 5. The average number of pupils in each class was 31.

Participants in our experiment consist of 30 pupils of third graders (15 boys and 15 girls) from the two primary schools. Selected pupils from each school were divided into 3 groups:
- Group1: learned multiplication in the traditional way.
- Group2: learned multiplication using our prototype on laptops.
- Group3: learned multiplication using our prototype on tablets.

Pupils in group 1, who learned in the traditional (no device) way, is considered as the control condition or the control group of the experiment, while pupils in group 3, who used tablet devices during mathematics learning, is considered as the main target group or in other words the experimental condition. The second group, who used laptops during the experiment, is interchangeably considered as target group (when compared with the first group) or control group (when compared with the third group). It should be mentioned that pupils with disabilities were excluded from the study. Parental consent was obtained for children’s participation in the project. For some reasons, mainly due to illness, some of the pupils could not participate in all the sessions. In general, 28 pupils participated in all the sessions and two pupils missed one of the sessions.
5 TECHNICAL APPROACH FOR PROTOTYPE DESIGN

Here, we discuss the technical approach to design our prototype. We describe different features of developing the prototype and explain the implementation process in more detail. The prototype is a mobile web application which aims to help children learn time and related mathematical concepts like time tables using touch features available on tablets. Our focus in this work is children aged 7 to 9. The main features of our application are:

- Touch to manipulate the specific pictures created for telling the time
- The use of interactive pictures

The core technologies that have been used to fulfill all the functionalities of our system are:

- HTML5
- CSS3
- JavaScript

5.1 Motivating Factors for Technical Platform Choice

Huge numbers of projects that have been developed using HTML5 indicate the considerable potential of HTML5 in designing web and mobile applications when combined with CSS3 (Baker, 2014). Baker (2014) names HTML5 plus CSS3 responsive web design, which allows a website to look good on all devices (desktops, tablets, and phones), and also states that it improves designing accessible web pages. Thus, by using HTML5 and CSS3 we are able to create a responsive web design. Responsive web design provides several advantages for our prototype:

i. Improves user experience (Lestari et al., 2014)
ii. Looks good on any screen size (Frain, 2012)
iii. There is no need for maintaining a mobile friendly site. So it saves time and money (Baturay & Birtane, 2013).

We have used new features of HTML5, such as “canvas” and “drag and drop” APIs to provide interactivity in our prototype. One of the reasons for using HTML5 to create our prototype is that unlike the older versions of html, with HTML5 we can create a prototype without mastering different techniques (Ratha et al., 2018). HTML5 offers new elements and APIs that are very useful during an app development process. It provides some APIs, such as
canvas element API and drag and drop API, that we use them to implement the specified functionalities in our application. Using the HTML5 <audio> element, we could embed audio in our application in a standard way without a need to use any plug-in (like flash). Another issue of the older versions is the browser compatibility. Since we are developing a mobile web application, which must work on different platforms with multiple web browsers, our prototype should be cross browser compatible. This problem was solved using HTML5 (Ochin, 2011).

Another factor that motivated us to use HTML5 as the main technology for creating the prototype was that this technology makes the implementation of a video in mobile and tablet devices much easier. HTML5 videos work out on most modern browsers. To make sure that users can watch the video on different browsers, it is crucial to convert the video file into the appropriate formats. To achieve this goal, we used EasyHTML5Video as an html video converter to convert the video into different formats.

As mentioned earlier, the aim of our prototype is to design a system for pupils to learn multiplication in an interactive way. To achieve this goal, we have designed a system that allows pupils to learn multiplication on a clock face. The interactivity was brought to our system by using the “drag and drop” API as a User Interface concept. Using this API, pupils are able to drag and drop items with the help of mouse click. In order to make the drag and drop functionality work on touch devices such as tablets, we have used the jQuery touch punch. Since the drag and drop API does not follow touch events, “Touch Punch” comes in to handle the mapping of touch events.

Another feature of our prototype is that it should be accessible on all popular desktop PCs, smartphones and tablets. To accomplish this feature, we used jQuery mobile. JQuery Mobile is a web framework compatible with touch enabled devices, like smartphones and tablet computers1. Using JQuery Mobile makes our application accessible on all kinds of desktop devices, smartphones and tablets.

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5.2 System Architecture

The following picture (figure 8) is an overall view of our system, it illustrates the components that make up our application. As shown in this picture, elementary school pupils are the major users of our system. The main technologies that have been used to create the app are HTML5, CSS3 and JavaScript. Users can interact with the system using different technological tools like desktop computers, laptops and mobile devices such as tablets or smartphones. Using HTML5 APIs, like drag and drop and also Canvas element API, add more interactivity to our prototype. JQuery mobile as an HTML5-based user interface system has made it possible to access the prototype on a wide variety of smartphones and tablet computers.

JavaScript is a scripting language that allows rendering dynamic HTML codes without access to a remote server. The role of JavaScript in enhancing the real performance of applications becomes more apparent when it comes to implement a mobile application. That is because mobile devices have low processing power and bandwidth access comparing to desktop computers. Using JavaScript along with HTML5 elements provides rich user interface experience by minimizing the round-trips to servers. CSS3 has a significant role in setting the visual style of our prototype.

![Figure 8 - An overall overview of our system](image-url)
5.3 Architectural patterns

In this section, we describe some of the architectural patterns of our system using a sequence diagram. A sequence diagram is a UML interaction diagram that shows the sequence of massages that are being exchanged between different objects. It indicates how and in what order different objects operate with one another to carry out the functionality of the system. The following sequence diagram (figure 9) describes an interaction with our system focusing on the sequence of massages that are exchanged when user wants to practice multiplication using the prototype.

As mentioned earlier, the prototype can be used either on a desktop computer applying mouse events or touch devices such as tablets and smartphones. Here, we assume that the prototype is being used on a desktop computer. By clicking on start button on the first page, different actions are shown: “Learn”, “Practice” and “Test”. If user clicks on “Practice”, (s) he has two options to choose from: “Practice1” and “Practice2”. “Practice2” includes some questions for user to practice. As long as there are questions, user must answer the questions and then click “Done”. The answer will be checked by “checkAnswer” function. If the answer is correct, next question will pop up. Otherwise, there are two cases. First, the value of “Number1” or “Number2” is not correct, in which case user must try again. Second the value of “Result” is not correct. If this happens, the value of “Result” which is “Number1 * Number2” will be calculated and displayed by “Calculate” function. A wrong answer is an opportunity for a learning moment. Providing visual feedback for the wrong answer is encouraging for children. We did not find text-based learning useful for preschool-aged children, because they are not that good at reading. Therefore, the “Learning” section is reinforced with visual audio and video representation.
5.4 Usage scenario

In this section, we describe how pupils can use our prototype to learn multiplication. We provide a picture of the pupils’ experience when using our system in the form of a scenario. There are different forms of scenarios, such as storyboards, comic strips, videos and scenario mapping. We use the scenario mapping to map out all the steps that a pupil takes to learn multiplication with our prototype. In the scenario map (figure 10), the main steps are mapped.
horizontally from left to right and details (comments or questions) associated with each step are mapped vertically.

**Scenario map**

Ronica — The student

Using “Multiplication Clock” app to practice multiplication

As seen in the scenario map, in the first step a pupil named Ronica opens the browser on her tablet and types in the URL, where our application is hosted. When she starts the application (figure 11), an interface appears with 3 options for Ronica to choose from (figure 12).
Ronica selects “Practice”. She gets redirected to the “Practice” page with 2 options (figure 13). Here, Ronica picks “Practice1”. There are different multiplication fact family that Ronica can choose (figure 14/left panel). She picks multiplication fact 5 and gets redirected to “practice 1” interface (figure 14/right panel).
Figure 13- Screenshot of prototype: Practice page with two options for user to choose from.

Figure 14- Screenshot of prototype: different multiplication fact family that user can select (left panel) and Interface of Practice1, which user should change the time by dragging the hour/minute hands and guess the multiplication fact that minute hand represents(right panel).

The aim of “Practice1” is to help pupils practice multiplication facts by answering the questions. The method that pupils use to answer the questions is skip counting on clock face. Besides practicing the multiplication, it is also a good opportunity for children to put their knowledge of clock reading into practice. If the pupil can find the right answer, the next question will pop up. Otherwise, she can try again and put the right answer. In case she doesn’t find the right answer, the correct answer will be shown. The pupil can press the “Home” button to get to the main page and select another activity to do (Figure 15).
Figure 15- Screenshot of the Home page of the prototype

The prototype is hosted in the following URL:

http://clockmultip.eu5.org/Prototype/index.html
6 EVALUATION SESSION

After designing and finalizing the desired prototype, it is time for real test and experiment with pupils accomplished through organizing evaluation sessions. As stated previously, before starting the main evaluation sessions we had two meetings: one a coordination meeting with teachers to provide them with details about the evaluation sessions of our prototype, and the other introductory meeting with pupils to help them get familiar with our system. Afterwards, in order to measure the level of pupils’ knowledge of multiplications, children were given a math test consisting of 7 simple multiplication problems. They were encouraged to use their own strategy in solving the problems. We then asked their motivation behind the strategy choice. According to Wu et al., (2008) children in this age range can describe their strategy choice. The pupils were graded by teachers at the beginning stage. The same testing and grading procedure were also done at the end after all the sessions. Comparing pupils’ grades before and after the learning process with or without our prototype was the main criteria to study the effect of touch features of tablets on children’s learning.

After the preliminary test, with the help of teachers we divided the pupils into three groups:

1. Group1- This group learned multiplication in the traditional way without using any system
2. Group2- This group used the prototype on laptop. In this group, children used mouse to interact with the system.
3. Group3- This group used tablets to work with our system; meaning to use touch features of tablets.

6.1 Evaluation Procedure

Here, we provide more information about the evaluation process of our project. The whole evaluation sessions lasted about six days. The first day was the orientation session, which aimed to introduce the system to the participants and help them get familiar with the system.

We also divided children into three groups with the help of teachers. We helped them connect their laptops and tablets to the Internet, which was a tedious work because of the Internet connection. We also conducted a test to measure the preliminary knowledge of pupils in multiplication.
The next two days were the regular training sessions. During these two days, each group used its own previously defined method for learning the same multiplication fact. It should be stated that the prototype is designed to teach multiplication facts 1 to 9. For the aim of our work, we only focused on multiplication fact 5. The pupils had the possibility to test their improvements at the end of each session. In the fourth day, all children were given the final multiplication test consisting of seven problems. We designed the multiplication tests with supervision of teachers.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Multiplication Fact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5 \times 5</td>
</tr>
<tr>
<td>2</td>
<td>5 \times 2</td>
</tr>
<tr>
<td>3</td>
<td>5 \times 4</td>
</tr>
<tr>
<td>4</td>
<td>1 \times 5</td>
</tr>
<tr>
<td>5</td>
<td>3 \times 5</td>
</tr>
<tr>
<td>6</td>
<td>5 \times 6</td>
</tr>
<tr>
<td>7</td>
<td>7 \times 5</td>
</tr>
</tbody>
</table>

*Table 2- Preliminary test*

<table>
<thead>
<tr>
<th>Problem</th>
<th>Multiplication Fact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5 \times 4</td>
</tr>
<tr>
<td>2</td>
<td>7 \times 5</td>
</tr>
<tr>
<td>3</td>
<td>5 \times 5</td>
</tr>
<tr>
<td>4</td>
<td>1 \times 5</td>
</tr>
<tr>
<td>5</td>
<td>8 \times 5</td>
</tr>
<tr>
<td>6</td>
<td>5 \times 2</td>
</tr>
<tr>
<td>7</td>
<td>3 \times 5</td>
</tr>
</tbody>
</table>

*Table 3- Final test*

As seen in tables 2 and 3, variation is visible in these multiplication problem sets. To capture children’s learning improvements during the study, we used a different range of
difficulty, as Van der Ven et al., (2012) state variability is important when learning new skills like mathematics. The order of the problems is also randomized.

The grading system used by teachers to report pupils’ progress was letter grading. The letters are A, B, C, D and F, A being the highest and F representing failure, the lowest. This grading approach is being used in Iran to evaluate pupils’ performance. But for the aim of our research, we used the grading based on 20 to be more quantitative. Grading results are given in table 4.

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>student 1</td>
<td>5.7</td>
<td>2.8</td>
<td>8.6</td>
</tr>
<tr>
<td>student 2</td>
<td>0</td>
<td>2.8</td>
<td>8.6</td>
</tr>
<tr>
<td>student 3</td>
<td>2.8</td>
<td>5.7</td>
<td>2.8</td>
</tr>
<tr>
<td>student 4</td>
<td>8.6</td>
<td>0</td>
<td>5.7</td>
</tr>
<tr>
<td>student 5</td>
<td>0</td>
<td>8.6</td>
<td>0</td>
</tr>
<tr>
<td>student 6</td>
<td>5.7</td>
<td>5.7</td>
<td>2.8</td>
</tr>
<tr>
<td>student 7</td>
<td>2.8</td>
<td>5.7</td>
<td>2.8</td>
</tr>
<tr>
<td>student 8</td>
<td>5.7</td>
<td>2.8</td>
<td>5.7</td>
</tr>
<tr>
<td>student 9</td>
<td>2.8</td>
<td>0</td>
<td>2.8</td>
</tr>
<tr>
<td>student 10</td>
<td>2.8</td>
<td>2.8</td>
<td>5.7</td>
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<tr>
<td>Average</td>
<td>3.69</td>
<td>3.69</td>
<td>4.55</td>
</tr>
<tr>
<td>Variance</td>
<td>7.4032222</td>
<td>7.4032222</td>
<td>7.7472222</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>student 1</td>
<td>8.5</td>
<td>11.4</td>
<td>20</td>
</tr>
<tr>
<td>student 2</td>
<td>2.8</td>
<td>14.29</td>
<td>20</td>
</tr>
<tr>
<td>student 3</td>
<td>5.7</td>
<td>14.29</td>
<td>17.14</td>
</tr>
<tr>
<td>student 4</td>
<td>14.3</td>
<td>11.4</td>
<td>17.14</td>
</tr>
<tr>
<td>student 5</td>
<td>8.6</td>
<td>17.14</td>
<td>8.6</td>
</tr>
<tr>
<td>student 6</td>
<td>14.3</td>
<td>14.29</td>
<td>17.14</td>
</tr>
<tr>
<td>student 7</td>
<td>8.6</td>
<td>17.14</td>
<td>14.29</td>
</tr>
<tr>
<td>student 8</td>
<td>8.6</td>
<td>8.6</td>
<td>20</td>
</tr>
<tr>
<td>student 9</td>
<td>5.7</td>
<td>8.6</td>
<td>17.14</td>
</tr>
<tr>
<td>student 10</td>
<td>11.4</td>
<td>11.4</td>
<td>17.14</td>
</tr>
<tr>
<td>Average</td>
<td>8.85</td>
<td>12.855</td>
<td>16.859</td>
</tr>
<tr>
<td>Variance</td>
<td>13.629444</td>
<td>9.4956944</td>
<td>11.64481</td>
</tr>
</tbody>
</table>

*Table 4* - Grading results of pupils before the training sessions (left panel) and after the training sessions (right panel)

In the fifth day, we ran some interviews with the pupils to ask about their experience of working with our system. Enthusiasm form children's faces were visible, so that almost all were asking about the URL address of the prototype to try it at home. We also interviewed teachers and asked them to fill out our questionnaire. In the sixth day, we classified all the information gathered during the past days to get them ready for the analysis part of the study.
6.2 Evaluation methods

Besides the above quantitative assessment, we have also considered a number of other mechanisms to conduct our evaluation process, such as observation, interviews, and questionnaires. More details of these methods are explained below.

➢ Observation

One approach in collecting data was observing the pupils’ behavior during the sessions. This helped us to study the extent to which pupils were interacting with the app and other classmates. Egloff (2004) indicate that the best method for evaluating preschoolers using a product is observation. During observation sessions, we look at the pupils’ behavior and actions when interacting with our prototype and also their positive or negative attitudes by observing the body language of pupils, like smiles, frowns, yawns and staring. As we observed, pupils in tablet group looked more interactive, energetic, happier and speaking louder, while these emotions were less in the second laptop/PC group. The least positive emotions were observed in the first group, who used traditional method. We had children from traditional method, who were trying and negotiating to join the other two groups. Somehow, our observation might be seen in the following pictures (figure 16).

Figure 16- Some shots of our experiment environment
We also implemented “Think-Aloud” method. Think-aloud is one of the most effective techniques for studying individual differences while doing a specific task (Olson et al., 2018). As such, we asked children to verbalize their thinking while working with our prototype. However, the “Think-Aloud” method was not an easy task for all the pupils, since only few of them did follow the instruction and were able to verbalize their actions while doing them. We sometimes intervened on “Think-Aloud” process by asking pupils questions about their feelings when working with the prototype. At least one pupil in each group (of 3 groups) got encouraged to follow the “Think-Aloud” method. So for all 3 sample groups, we could collect children’s experiences of working with our system from their own points of view.

“Co-discovering” was another approach that we used with our product. In this approach, in each group we asked two pupils to use the prototype together. We observed their collaboration and conversations to gather information about the effectiveness of the tools that they use to learn multiplications. Adebisin et al., 2009 argue that think-aloud technique is more effective when it is combined with co-discovery method. They state that think-aloud combined with co-discovery involves two persons having a conversation and it reduces the level of intervention by examiner. The disadvantage of this method was that children did not like being distracted and interrupted while working with the prototype. We made notes of children’s behaviors and experiences during the evaluation process. The pupils’ body language was also a good clue of their positive or negative attitudes that helped us during the evaluation session.

➢ Interview

Since the main audience of our work were children aged 7 to 9, it was not easy to conduct the traditional paper-based evaluation method. Instead we thought it might be a better idea, if we conduct group interview before and after our experiment. Nevertheless, it was a bit problematic to get into real communication with children in this age range. So, we decided to gather 5 children in a group discussion instead of individual interviews. In the group discussion, we asked children’s ideas about different aspects of our prototype. The privilege of
group interview was that children answered the questions in a less stressful way, since they did not feel being observed with others.

The interview were conducted in both schools at a time convenient to teachers and pupils, with permission of parents. Since following the school curriculum was very important, we had to respect their time and try not to interrupt their plans. Five children were interviewed in each group. Same questions were asked from participants to have a structured interview. It was allowed to add extra information if needed. The outcome of the interviews was almost the same as our observation as discussed above.

➢ Questionnaires
In order to obtain feedbacks from teachers to conduct our study in general, and using technologies in teaching multiplications in particular, we prepared a series of questions (see
Appendix B). To evaluate children’s perception of multiplication after each session, we used a questionnaire with some simple and straightforward questions for pupils (see Appendix A). In this way, we could determine the popularity of the app among the pupils and improve its weaknesses.
7 DATA ANALYSIS

To make some sense of our data collected in the former section and provide an appropriate interpretation of our experimental results, we use statistical methods to analyze the collected data. We aim to discuss the statistical analysis here in this section. It should be mentioned that:

1. We put the analysis in the context of our research questions.
2. We use qualitative and quantitative methods for data analysis.

As discussed in the former Chapters, we have different methods of data collection: preliminary and final tests, observations, questionnaires, and interviews. Accordingly, we use quantitative and qualitative methods for data analysis. Qualitative data collection is mostly focused on observations, questionnaires and spoken interviews that we design to gather information. For qualitative analysis, we use interpretive analysis method, in which we describe in words the content of the participants’ answers and make notes about the participants’ feelings and reactions. To have a qualitative interpretation, we organized and categorized all pupils’ answers to each question of questionnaire and interview and also the notes we made during the learning and evaluation procedure. This could be a bit challenging, since one group of our interviewees are children and they might use different words to express their opinions and feelings. So, we applied the “peer-reviewing” method to analyze our qualitative data. Namely, we asked teachers, who were somehow aware of the scope and aim of our research, to play the role of peer-reviewer and review the texts, questionnaires and interviews’ results and highlight the key points.

Our qualitative observations during the learning and evaluation process could be classified into four categories:

- Curiosity and Willingness: Encouraged to think and ask valid questions.
- Engagement: Active participation in the classroom.
- Collaboration: Discuss and communicate with other pupils about the class activities.
- Fun: Enthusiasm and happiness observed from pupils’ face and actions.

With the help of teachers, we observed the above characteristics and made a qualitative assessment, which is shown in figure 18.
Figure 18- Qualitative assessment of the observation results based on the defined categories.

In questionnaire and interviews, we mainly focused on the following characteristics:

- Effectiveness
- Difficulty
- Enthusiasm
- Fun
- Satisfaction

Associated with each of these characteristics, we prepared some questions to ask pupils in an organized group interview or in the form of a questionnaire. So, we first defined these characteristics, i.e. effectiveness, difficulty, enthusiasm, fun and satisfaction, which fits to the overall process of our research design. We then tried to articulate our questions to address these characteristics. As one may see in the questions provided in appendix A, no questions were included unless it is associated in testing one or more of the defined characteristics. We categorized the questions depending on their characteristics and illustrated the pupils’ answers to the specified questions in percentage in figures 19, 20 and 21. Since, our associated evaluation was a qualitative one, we always tried to have teachers as reviewers with us.
Figure 19- Outcome of the analysis of the pupils’ answers to interviews and questionnaires in group 1

Figure 20- Outcome of the analysis of the pupils’ answers to interviews and questionnaires in group 2

Figure 21- Outcome of the analysis of the pupils’ answers to interviews and questionnaires in group 3
As seen from the above analyses illustrated in figures, our observation, questionnaire and interviews all indicate the same information that progress in the group 3 and positive impact of the touch-enabled learning method used in this group is much better than the other two groups. Therefore, one may conclude that touch features available on tablets is helpful to teach young children. However, as stated, this conclusion is based on a qualitative assessment of some observations and communications, where misjudgments, misunderstanding and miscommunications are unavoidable. Thus, to support and confirm the above result we further apply a quantitative analysis based on pre- and post-tests taken from pupils, which we shall discuss below.

The quantitative analysis were performed in two steps. The first step is considered as the initial data analysis and the second step provides more advanced statistical analysis. In the first step, we provide a summary of our dataset and compare the grades children obtained before and after the training sessions. We do some initial statistical analysis about means and variance of our data collected in the evaluation sessions as discussed in chapter 6. This leads to the creation of bar charts, where we examine if there is any significant difference between the three groups of our experiment. After these initial analysis, in the next step we move on to more advanced statistical analysis. We apply one-way analysis of variance (ANOVA) and a post-hoc test on top of ANOVA as well as an analysis on the average percentage of pupils’ progress. The results of our analysis in this step also show a significant difference between three groups of our participants. Moreover, these results confirm that children in the touch-enabled learning method (group 3) perform better than those in the other two groups.

7.1 Initial Analysis of Data

Here, we summarize the data obtained in chapter 6 in a way to extract some information regarding our study. We used bar charts to draw the data given in table 4 of chapter 6, which are the grades children obtained before and after the training sessions. Although it does not look easy to compare the grades of pupils in three groups before the training sessions, the corresponding chart in figure 22 shows that pupils in three groups are almost in the same range of multiplication knowledge. Figure 22 shows that after the training sessions, pupils in group 3 had better grades compared to the other two groups.
Figure 22- Bar charts summarizing the collected data given in table 4 of chapter 6. The horizontal axis shows the pupil number and the vertical axis shows the grade of each pupil in the corresponding group.

Looking at the grades children obtained before the training sessions shows that the grades in three groups range almost in a similar manner from 0 to 8.6. However the grades ranges after the training session are different to one another, especially in group 3 children record a higher grades range. Maximum grade after the training session for group 1 is 14.3, for group 2 is 17.14, whereas the maximum grade in group 3 is 20.

To get some idea about the size of the effect that each learning method had on children’s progress, in what follows we looked at the means and variances of the three groups. Figure 23 illustrates the means of the grades in each group before and after the training. Figure 24 shows the means differences or in other words means of grade differences before and after the training for each group, which one may relate to average amount of progress pupils in each group have made.
Figure 23- Means of groups for grades before and after the training sessions

Figure 24- Comparing the means of three groups. (Means of the differences between secondary and primary grades of pupils in 3 groups)

The means of the children’s grade before the training session are very close to each other, this means that children in three groups have almost the same knowledge of multiplications. However, the means of the three groups after the training sessions vary considerably. Group 3, who used tablets to learn multiplication, has the highest mean among the three groups. This might be interpreted that the most improvement belongs to group 3. We also looked at the differences of the means after and before the training for each group (figure 24). Group 3 again records the highest means difference, which indicates that pupils who used touch-enabled devices had higher learning progress than other pupils.
Spread of data can also be a good statistical method for analyzing the gathered data. For each group, we measured variances before and after the training. The result is shown in figure 25. Since variance measures how far a dataset spread out from their average value, if the group variances before and after the training remain close then one may argue that all the pupils in that group made almost the same progress in the learning process. As seen from figure 25, the variance for each group after the training increases and the lowest increase belongs to group 2. Our main target group, i.e., group 3, takes the second place in variance increase, however the increase is not very much.

Figure 25 - Variances before and after training for each group.

Although the basic statistical analysis of our data presented above show and highlight some differences between the three training groups, we cannot still claim if a significant difference occurs and where it occurs. To achieve a consistent conclusion, we did a more advanced analysis in the next section.

7.2 Testing for differences between experimental conditions

To examine if there is any significant difference between the three groups of our study, we use analysis of variance (ANOVA) test. We use ANOVA to analyze our experimental data, which
we here choose to be the data concerning the difference between the final (after training sessions) and the primary (before training sessions) grades of children in each group. Our sample data is given in table 5. Since our analysis concern three independent groups and have only a single independent variable (grads difference), the relevant ANOVA test is the one-way ANOVA. Associated one-way ANOVA hypothesis here assumes that the mean of group 3 (those who use our prototype on tablet to learn multiplication) is different than the means of the other two groups.

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.8</td>
<td>8.6</td>
<td>11.4</td>
</tr>
<tr>
<td>2.8</td>
<td>11.49</td>
<td>11.4</td>
</tr>
<tr>
<td>2.9</td>
<td>8.59</td>
<td>14.34</td>
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</tr>
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<td>2.9</td>
<td>8.6</td>
<td>14.34</td>
</tr>
<tr>
<td>8.6</td>
<td>8.6</td>
<td>11.44</td>
</tr>
</tbody>
</table>

*Table 5- Differences between secondary and primary grades of children in 3 groups*

The summary of the one-way ANOVA test in excel for our sample data in table 5 is shown in table 6.
Anova: Single Factor

**SUMMARY**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Count</th>
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<th>Average</th>
<th>Variance</th>
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</thead>
<tbody>
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<td>51.6</td>
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<tr>
<td>Group 2</td>
<td>10</td>
<td>91.65</td>
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</tr>
<tr>
<td>Group 3</td>
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<td>123.0</td>
<td>12.309</td>
<td>3.7699</td>
</tr>
</tbody>
</table>

**ANOVA**

<table>
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<tr>
<th>Source of Variation</th>
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<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F crit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
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<td>128.38</td>
<td>27.620</td>
<td>2.95E-07</td>
<td>3.3541</td>
</tr>
<tr>
<td>Within Groups</td>
<td>65</td>
<td>25</td>
<td>27</td>
<td>4.6482</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>382.27</td>
<td>29</td>
<td>29</td>
<td>29</td>
<td>29</td>
<td>91</td>
</tr>
</tbody>
</table>

Table 6- Single Factor ANOVA test for the three groups sample data.

As seen in Table 6, we have the F value (F=27.62082) to be greater than the F critical value (F crit = 3.354131). Thus, according to ANOVA, our null hypothesis, which is here the equality of three means for three groups, is rejected. In other words, we have different group means. Since the P value (P-value=2.95E-07) is smaller than our α level, which we here taken to be the usual value of α=0.05, implies that the differences between the means are significant.
Therefore, the one-way ANOVA test confirms our main hypothesis, i.e., the means of the three groups are significantly different.

Although the ANOVA analysis shows that there exist a statistically significant difference between the three groups of our study, it does not say if all the differences are statistically significant. Explicitly speaking, ANOVA cannot tell us which group perform significantly better than the other groups. In order to determine where the difference occurred between the groups and which of the means are significantly different from the others, we ran a post-hoc test on top of our ANOVA test. Among different post-hoc tests available, we used Games-Howell test which is used when group variances like our case are not equal. The test statistic q for each pair of group means is calculated and plotted in figure 26.

![Figure 26- q and q_critical values for each pair of group means in the Games-Howell test.](image)

As shown in figure 26, for each pair of groups the corresponding q value is greater than the corresponding q_critical, which indicates that the difference between each pair of the means is significant. Table 6 and figure 24 show that the highest mean belongs to group 3, the second highest is group 2 and the last mean is for group 1. The significant differences observed between groups 2 and 3 with group 1 imply that children who had a chance to use
technology for learning show significant progress compare to those who did not have access to technology. On the other hand, the main difference between group 2 and 3 in our experiment is the touch feature, where we also notice a significant difference in the children’s progress. From all these differences we conclude that the pupils involved in the leaning process of group 3, who used our prototype on touch-enabled devices like tablets, had significant progress compared to those pupils involved in the other two groups, who did not use touch-enabled devices. In other words, the major result of our experiment is that touch feature available on tablets has significant positive impacts on young children’s learning of mathematical concepts like time tables.

To further see that progress in group 3 was the highest among the three groups of our study, we also measured the average percentage of pupils’ progress for each group. In order to calculate this factor, we first measured the percentage of progress for each pupil as

\[
\text{Percentage of progress for a pupil} = \frac{(\text{pupil's grade after training} - \text{pupil's grade before training}) \times 100}{20}
\]

And then take the average over all the percentages in each group. Table 7 and figure 27 show the average percentage of pupils’ progress in three groups.

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average percentage of pupils’ progress</td>
<td>25.8</td>
<td>45.825</td>
<td>61.545</td>
</tr>
</tbody>
</table>

*Table 7- Average percentage of pupils’ progress in 3 groups*

*Figure 27- Schematic diagram of the average percentage of pupils' progress given in table 7*
As seen in table 7 and also figure 27, the most progress belongs to group 3 who used tablet to interact with our system.
8 DISCUSSION

Traditional ways of teaching in math education may develop pupils who are not interested in learning math and they only want to pass their lessons and finish the academic year. In this study, we demonstrate that we can change this trend and raise pupils, who are more motivated and enthusiastic in learning, by deploying technology in their educational journey. The present study shows that the utilization of tablet devices in the learning environment have positive impact on children’s motivation, attitude and achievements.

Our study set out to assess the effect of touch-based devices like tablets on enhancing children’s learning of mathematical concepts. We investigate if touch-enabled devices could provide opportunities for pupils in the educational world and help them learn mathematics. We were after finding some answers for the following questions:

RQ1- What do teachers think are effective uses of mobile technologies to enhance children’s learning and what barriers are there to more effective use of them?

This study demonstrates that touch features of tablets has positive effect on children’s learning multiplication facts. We carried out an experiment with a selected sample of 30 pupils from two primary schools, who were divided into three groups as:

1. Group who learned multiplication facts in the traditional way.
2. Group who learned multiplication facts using our prototype on laptop.
3. Group who learned multiplication facts using our prototype on tablets with emphasize on using the touch feature of tablets.

Our tests and examination of this experiment show that children in group 3 had the highest improvement compared to the other two groups. We provide some evidence that technology usage in schools can increase motivation and interaction among pupils’ learning mathematics.

Teachers of our study were involved in all the evaluation process of our research and they observed pupils working with our prototype. Although the teachers were a bit unsure at the beginning of the experiment, at the end they mostly agreed that applying mobile technologies in the classroom is not only engaging, but is also educational. Teachers said that
according to the experience they gained through our research, tablet technologies make positive changes in how pupils learn. However, they confessed that this was their first experience of applying technology in classroom and because of the limited scope of our study, they were not completely sure about deploying technology in their future classes. What they were absolutely sure about was that applying technology in the classroom is not just about simply adding them to the learning process, while there must be a well-designed plan for the creative deployment of these technologies in classroom, which is based upon the learning experiences. They also insisted that there must be a set of rules and principles that pupils need to follow in order to achieve educational goals. Furthermore, teachers brought up a number of concerns, some of which are as follow:

1. Using tablets may be a source of distraction in the teaching process.
2. Lack of teachers’ expertise with technology is one of the concerns regarding harnessing technology in the classroom. Teachers must receive proper training to adapt technology in classroom.
3. The level of the familiarity of children with technology was also a teachers’ concern. Some low-income pupils don’t have access to technology as their other classmates do. So, they don’t have the opportunity to practice their homework outside of schools and they may fall behind the lessons.

Although these concerns might constitute some deal breakers among school staff and parents, but teachers involved in our study note that the benefits of applying tablets in the educational curriculums may dominate its drawbacks by a well-defined plan.

**RQ2- What particular features of tablets do the teachers think can be more engaging for children and facilitate the learning process?**

This study provides a proof of concept for the effect of tablets on children’s learning. The key feature of tablets, which is touchscreen, reveals new ways of interaction among teachers and pupils. This feature of iPad along other features like mobility, access to the internet and different educational apps make iPads appealing for both pupils and teachers and can support children’s learning. Teachers of our study confessed that iPads not only had positive impact on children’s mathematics learning, but also enhanced their communication skills and this
helped them to be more interactive during the lessons. They also mentioned that pupils were more enthused and motivated to learn the topics when using tablets comparing to the traditional and even laptop/PC based teaching. However, teachers believed that using tablet for relatively long period of time in the class looked a bit distracting, so that teachers were losing pupils attentions. This means that using tablet devices alone in the classroom may not guarantee improvements in pupils’ educations. Perhaps this can be managed by having a well-defined and clear plan in deploying tablets in the school curriculum, as mentioned before.

**RQ3-In which ways can the utilization of the interactive features of touch-enabled devices be used to enhance learning content (for example, graphics) to foster the learning of pupils and positively change the way children experience the learning?**

As we observe in our study, using interactive pictures during the teaching process could improve children’s learning and memorizing capabilities. Although there were individual differences in the learning and catching capabilities of pupils, but all the pupils were very eager to work with interactive pictures and this helped them to learn in a more efficient and enjoyable way. In the traditional teacher-centered educational methods, which is mostly focused on the memorization of the content, especially when it comes to timetables, pupils are less active and less creative in the classroom comparing to the new approaches which uses interactive contents, such as text, picture or animation. Applying interactive features of touch-based devices, such as tablets, during the learning process helps children grasp the contents better and easily remember the subjects being taught as well as improve their memory skill. In fact, our study implies that the influence of learning with educational tools equipped with interactive contents should not be disregarded. To some extent our study would be a confirmation of the study by Islam et al., (2014), where they point out that the most exciting part of multimedia technology integration in schools is interacting with interesting contents rather than traditional reading and memorizing. Islam et al., (2014) indicate that applying interactive media in the teaching process could make learning more exciting and the delivery of knowledge much easier. Deploying interactive features into tablet devices makes the presented information in our application more noticeable for users and attracts their visual
attention. So, it helps for better understanding of the content and keeps children’s brain remain engaged. Besides, it increases pupil’s motivation in learning, supports their understanding and stimulates thinking by looking and referring to the visual memory.

**RQ4-What opportunities these technologies may provide in the educational world and are these opportunities outweighing the challenges of using mobile devices in school?**

Applying tablets in the learning process could provide some advantages and possibilities for the stakeholders, some of which are as follows:

- Children can learn by using of interactive pictures on interactive whiteboards, which are easier than paper books.
- Tablet technology can increase pupils’ enthusiasm in learning and support their understanding.
- In the traditional way of learning, teachers need to implement multitude learning styles in the classroom, since not all children have the same learning backgrounds and their learning pace and interests differ as well. By using mobile devices, like tablets, they can somehow overcome this barrier and present a course in a variety of ways. For instance, they can show educational videos or ask pupils play educational games.
- Tablet devices could improve pupils’ creativity and help them discover new ways of learning. So this way, pupils are not just some passive learners anymore and teachers can deliver some creative forces to the society.
- Teachers also benefit a lot. They are empowered with technology and away from tedious traditional teaching approaches and grading, and can concentrate more on teaching.

Besides these opportunities, tablets might bring some disadvantages as well, some of which mentioned as teachers’ concerns in the discussion of RQ1. However, as the teachers involved in our study also stressed, opportunities and advantages outweigh the disadvantages if the teachers could handle using tablets with a well-defined plan in the classroom.

Our finding that children’s performance in multiplication fact had significant growth after using tablets in the learning process is not merely new. The results of our study are
broadly consistent with the findings reported in previous literatures. For instance, the results of the study conducted by Outhwaite et al., (2017) show significant impacts of tablet technology on developing early math skills of primary school children in the UK. Pichford (2015) also approves the positive impact of hand-held tablet technology on children as a beneficial learning tool. Schacter and Jo (2016) is another witness to this claim. Schacter and Jo (2016) illustrate improved mathematics performance of children using tablet technology in preschool.

Our study show that deeper understanding of new technologies are needed among pupils and school staff. To our knowledge, this is one of the few studies to examine the effect of touch features of tablets on children’s learning multiplication facts using clock reading in preschool and primary years. Much more work is needed to convince school staff and parents to believe on the impact of tablets on pupils’ multiplication learning. This study was done in the field of multiplication learning using mobile devices like tablets, but the findings could be generalized to other math topics, such as division, subtraction and addition. There are a number of issues that should be resolved in the future works. For instance, there were some low-income children in our study who were not much familiar with technology and they got into trouble when working with our prototype using the mouse, however this problem was resolved to some extent by the end of the study. Drag and drop for pupils working with tablets was easier than those working with laptop devices. The general problem that children in both group encountered was the low speed of Internet. One of the drawbacks of this prototype was that pupils had to fully understand the clock reading, otherwise they would encounter problems.

This study provides useful recommendations for better use of tablets in schools for potential users of tablets. Besides, it was a good opportunity to examine the implications of introducing tablets into educational settings in schools in developing countries like Iran. Studies in the field of tablet usage in schools are mostly conducted in developed countries. So, further studies need to be done to explore the role of tablets in enhancing children’s knowledge of mathematics in developing countries. Nevertheless, this short time was a good opportunity for us to discover some points to apply in our future works:

- One point, which got clear by pupils working with the system, was that for multiplication fact 5 pupils could look at the number inside the clock face instead of
counting the arrows around the clock. This way, they could solve the problems faster. Hence, one of the benefits of working with children was stimulating children’s creativity, so we could discover the points that have been unclear to us.

- Another advantage of this study was evoking the sense of interaction and cooperation among pupils. We saw pupils helping their friends in case there was a problem. One of the things that caught our attention was that pupils were very eager to work with our system rather than learning in the traditional way and we saw more improvements in pupils’ learning multiplication facts.

- One benefit of this project was that working with our system not only helps pupils learn multiplication facts, but also it is a good opportunity for them to improve their knowledge of clock reading.

- The level of interest and accuracy among girl pupils were more than boys. Although boys did not show much interest to work with us at the beginning and they were even escaping from us, but after working with our system they showed a great desire to cooperate. All the children were so eager to have the prototype and work on their own at home.

In spite of the considerable number of researches conducted in this field and that the results of our study demonstrate that using tablets in teaching multiplication have positive impacts on pupils’ learning, there are still many uncertainties among parents and school staff about applying tablets and other mobile devices in the school context. So, more investigations are required in this regard to examine the impact of tablets on children’s learning from different points of views, particularly in developing countries. One of the things, which needs more examination about applying tablets in school context, is the very different access to these devices. If school ask pupils to bring their own devices, then one pupil may bring an iPad with the best performance, screen quality and many other features, while another pupil might not have even the oldest version of the devices. On the other hand, if school takes the responsibility to provide the same devices for all the pupils, then this could also be problematic, since teachers have to always be concern about the devices and keep track of them. Thus, they might lose their concentration on teaching.
9 CONCLUSION

This research illustrates that children’s learning of multiplication could be enhanced by integrating tablets into the educational context. We observe that using tablets in the learning process makes learning fun, interactive and engaging. In this study, we examine the hypothesis that the use of tablets in schools enhances children’s learning of multiplication by: (1) touch features available on tablets to manipulate specific pictures and (2) the use of interactive pictures. Our results indicate that this hypothesis is true and the use of tablets is beneficial to increase pupils' performance in math. This study is another approval of all the researches done in the field of mobile learning and is mainly focused on the use of touch-enabled devices in the learning process. Equipping children with new technologies such as tablets could help them get motivated and engaged in their educational journey. During the evaluation process of our study, almost all the pupils confess that integrating tablets in the educational settings can provide many opportunities for them. The results of our study shows that pupils, who have the opportunity to use touch-enabled devices like mobiles and tablets for learning multiplications, have the highest progress compared to those, who learn multiplications without using touch-enabled devices.

Teaching some subjects of mathematics such as multiplication is a boring concept for both pupils and teachers. However, teachers should try to motivate pupils to learn such abstract concepts. One solution to this issue could be applying new technologies in math learning process. Teachers have a big mission to guide pupils’ passions for learning in the right path from the early years of schools. One reason for our study was to approve that tablet and mobile devices not only are not destructive phenomena, but can help pupils in the learning process and improve their knowledge. As we illustrate in this study, touch features available on tablets are beneficial to teach children about mathematical concepts.

For the purpose of our study, we develop a web-based mobile application for learning multiplication facts and conduct a series of case studies, individual interviews and questionnaires. We first collect the requirements and specifications based on the real needs of pupils with the help of teachers in some meeting arranged with teachers and pupils. We then convert these requirements into particular design features and develop the prototype of our work. We test the designed prototype in an experiment conducted with 30 primary school pupils selected from two schools in Iran. The pupils are divided into three groups, where one
group use our prototype on touch-enabled devices like tablet, one group use the prototype on laptop/PC without touch feature, and the other group follows the traditional way to learn multiplication. We observe that children involved in the leaning process of group 3, who use our prototype on touch-enabled devices, have significant progress compared to those involve in the other two groups, who do not use touch-enabled devices. Thus, the outcome of our research shows that using touch-enabled devices such as mobile phones and tablets not only can increase pupils’ motivations in learning, but also provides a good opportunity for pupils to improve their knowledge of learning. Our study explores the main reasons, i.e., touch feature, underlying the use of tablets in the educational settings.

Studying the effect of touch-enabled devices has been particularly the focus of this work. Although there exist a number of works including ours in this field of study, this research topic is still in its adolescence and further studies would help improve our understanding on the effect of touch-based learning on children’s understanding of mathematical concepts. We have gained great experience during this thesis project. In future studies, we would like to continue exploring the subject with more focus on seeking the effect of touch-enabled devices on children’s learning different subjects of their curriculum. Because of the small sample of pupils involved in our research, we plan to repeat our experiment with more number of children. We hope that this study with other similar studies that have been done so far, could modify attitudes and patterns of some parents and school staff who are still uncertain about the influence of mobile devices on children’s knowledge and behavior.
10 LIMITATIONS

Besides the novelty and strengths, each experimental research has its own limitations as well. Our experiment was not an exception and we had some inevitable limitations, some of which are as follows:

- Because of the time limit, this research was conducted in two primary schools for about six days, which is considerably a short period of time for observing all the events and performance of the pupils. In addition, since the schools in our study were single-six we were forced to do each steps of the experiment twice, namely once in the girls’ school and once in the boys’ school.

- Another limitation in our study was related to the population of the sample groups. Because of the lack of facilities, we selected 30 children from two primary schools divided into three groups, where we had sample size of only 10 pupils in each group. The small sample sizes used in our experimental research might have adverse effect on validity, reliability and precision of our results in a larger scale.

- Since the author herself involved in the evaluation session, pre-test and post-test, some sort of subjectivity might be seen in this research. The results would have been more trustable and generalizable if a neutral person had conducted these parts.

- In this research, we have used some sort of questionnaires for pupils and teachers. Our users intentionally or unintentionally might have not provided real answers for questions and the answers might be unrealistic. Although we have tried not to include too many questions in the questionnaires, but still there is a chance that some pupils might not provide accurate responses for the questions.

- Finally, the slow network connection was a bit discouraging and might have affected children’s performance.
11 REFERENCES


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12 Appendices

Appendix A: Questionnaire for Students

Dear pupils,

First of all, I need to thank you for your participation in this research program. The aim of this research is to examine if touch features of tablets has any effect on children’s learning multiplication. Your opinion is so important and effective in the results of this study. All of your answers will be kept confidential. Certainly I don’t need to remind you that your careful answers to the questions will correctly guide us in the conclusion of the research.

Thank you for sharing your thoughts with us.

Q1. How much has your interest in learning multiplication increased?
☐ Very little
☐ Little
☐ Average
☐ Much
☐ Very much

Q2. How much do you think this method helped you to learn the material?
☐ Very little
☐ Little
☐ Average
☐ Much
☐ Very much

Q3. How much progress do you think you have made in your group?
☐ Very little
☐ Little
☐ Average
☐ Much
☐ Very much

Q4. How difficult did you find learning multiplication?
Q5. How challenging did you find the method you used in learning multiplication?
☐ Very little
☐ Little
☐ Average
☐ Much
☐ Very much

Q6. How much did you like the way you learned multiplication in this study?
☐ Very little
☐ Little
☐ Average
☐ Much
☐ Very much

Q7. If you had the right to choose the method of learning multiplication in our study, how likely is that you would attend the same group you were participating during our study?
☐ Very little
☐ Little
☐ Average
☐ Much
☐ Very much

Q8. How much did you enjoy learning multiplication?
☐ Very little
☐ Little
☐ Average
☐ Much
☐ Very much

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Q9. To what extent do you agree with this statement: I had very much fun learning multiplication in my group?
☐ Very little
☐ Little
☐ Average
☐ Much
☐ Very much

Q10. How easy it was to catch up the lessons in the way you learned multiplication?
☐ Very little
☐ Little
☐ Average
☐ Much
☐ Very much

Appendix B: Questionnaire for teachers

Dear teachers,

First of all, I need to thank you for your participation in this research program. The aim of this research is to examine if touch features of tablets has any effect on children’s learning multiplication. Your opinion is so important and effective in the results of this study. All of your answers will be kept confidential. Certainly I don’t need to remind you that your careful answers to the questions will correctly guide us in the conclusion of the research.

Thank you for sharing your thoughts with us.

Q1. How many pupils do you have in your class?
   Click here to enter text.

Q2. How important is the subject of multiplication in your mathematics class?
   ☐ Very important
   ☐ Important
   ☐ Not so important
   ☐ Not important at all
Q3. What method do you use in teaching multiplication?
   Click here to enter text.

Q4. Approximately what percentage of your weekly teaching time is based on traditional ways of teaching multiplication?
   ☐ 0-25%
   ☐ 26%-50%
   ☐ 51%-75%
   ☐ 76%-100%

Q5a. Are the pupils allowed to use any types of technology during the mathematics lessons?
   ☐ Yes
   ☐ No

Q5b. If yes, which technology they use the most?
   ☐ Laptop PCs
   ☐ Smart phones
   ☐ Tablets

Q6. How do pupils work in the class?
   ☐ Individually with assistance from the teacher
   ☐ Individually without assistance from the teacher
   ☐ In small groups with assistance from the teacher
   ☐ In small groups without assistance from the teacher

Q7. What percentage of the class curriculum (how many weeks of the curriculum) is spent on teaching multiplication? Write a percentage
   Click here to enter text.

Q8. To what extent do you think the current method of teaching multiplication is effective?
   ☐ Not at all
   ☐ A little
   ☐ Quite a lot
Very much

Q9. To what extent do you usually assign multiplication homework?
☐ Every day
☐ 3 or 4 times a week
☐ Once or twice a week
☐ Less than once a week
☐ Not at all

Q10. If you assign written homework to your students, how often do you collect and correct the assignments?
☐ Never
☐ Rarely
☐ Occasionally
☐ Always

Q11. How often do you give feedback on homework to the pupils?
☐ Never
☐ Rarely
☐ Occasionally
☐ Always

Q12. How do you assess the work of the pupils in learning mathematical concepts, like timetable?
☐ Standardized tests, such as multiple choice, true-false and matching tests
☐ Students' grade on homework assignments
☐ Observation
☐ Response of students in class
Q13. How much do you think applying new technologies in teaching multiplication can reduce load work of teachers in the class?
☐ None
☐ Little
☐ Quite a lot
☐ Very much

Q14. How much do you think applying new technologies in teaching multiplication can improve pupils' learning achievements?
☐ None
☐ Little
☐ Quite a lot
☐ Very much

Q15. Do you agree with the use of new technologies in the educational system, especially in teaching mathematics subjects, such as timetables?
☐ Yes
☐ No

Q16. What type of technology do you think can be more effective?
☐ Computers with mouse events
☐ Tablets with touch events

Appendix C

i. Results of first interview with teachers and pupils:

Having teachers’ opinions about the difficulties that children might encounter in using traditional materials can help us to design more efficient and interactive learning environments. The results of our interviews show that teachers apply different methods when teaching multiplication problems, such as arrays, number lines, counting by fingers, repeated addition, and skip counting. But they have never applied new mobile technologies in the teaching process. In the interview, teachers stated that they make use of practical equipment that are being used
in everyday life, such as egg boxes, chocolate boxes, fruits, etc. They mentioned that one of the effective ways that they use in teaching multiplication is skip counting. To encourage children to apply skip counting as a strategy to solve multiplication problems, they use a number line, as follows:

They recommended that we could apply the skip counting method on a clock face and make the learning process more fun and enjoyable. This way children not only can improve their knowledge of clock, but also they will learn the multiplication in an innovative way.

As I talked with the teachers, one of the issues that children encounter when learning mathematics is that children don’t focus on the word problem when solving the problems. They suggested that we should design the app in a way that encourages children to underline/highlight important words and numbers. So they can verify what they have to find. Therefore the learning part of the app is started by a problem set. As discussed before, the main problem that pupils have in telling the time is mostly focused on misreading the numbers and misinterpretation of these numbers. Mixing up the functions of the hour and minute hand is another type of error.

Teaching timetables on clock face using skip counting can help children differentiate the function of the hour and minute hands. One of the things that teachers emphasized to consider during the app development process was to design the app in a way that help pupils improve their knowledge of multiplication on a clock face not cause them forget their knowledge of clock reading. Teachers believed that learning multiplication fact on clock face might cause pupils mix up two mathematical concepts (the concept of multiplication and clock reading) or even cause pupils forget their knowledge of clock reading instead of helping them get improved in multiplication.

In the initial interview with teachers, we first talked about the importance of learning multiplications and the current methods that they use in teaching this concept. We talked about the advantages and disadvantages of the applied methods. They were happy with the currently used methods in teaching multiplication, the only thing that they brought up as disadvantage for their methods was lack of concentration and attention. They pointed out that some of pupils do not show enough attention and interest to learn multiplication. Teachers believed that we should try to catch children’s attention and increase their interest. When we shared our idea with teachers, they welcomed the idea. They believed that with this method we could increase pupils’ accuracy and motivation in learning multiplication. They suggested that we should design the app in a way that help children increase their concentration.
ii. Results of second interview with teachers after making the prototype

After creating the prototype, we organized some meetings with the teachers to check if the prototype meets their expectations. In this meeting, we asked teachers to work with our system and give us their feedback. They first examined the layout and appearance of the app. They were quite satisfied in this regard. Teachers stated that the current prototype was connected to what we had discussed before and it somehow met their expectations. Nevertheless they provided some suggestions to improve the prototype. One of the things that they emphasized even in the first meetings was try not to focus too much on clock and cause children mix up these two concepts. They stated that we have been able to fulfill this expectation. Teachers recommended to include a set of instructions in the prototype to help pupils learn how to use the app. Another thing that they mentioned as an improvement of our application was to add sound to each part of the app instead of writing text. Since pupils at this age range are not so good and fast at reading texts. Another suggestion was that although children learn multiplication facts by skip counting on a number line, but it would be a bit challenging for them to skip count on a clock face. Therefore, they recommended to get pupils familiar with this concept and explain how skip counting on clock face works. They also recommended to interchange “Practice1” and “Practice2”, since these two parts are in the same direction. So pupils can first do the “Practice1” and get ready for the “Practice2”.

We applied teachers’ feedback in the application, to get them motivated to continue with our study. We added a part called “instruction” to our prototype as teachers mentioned in their interview. This part added as one of the main parts of the application. So pupils can first go through the instruction part to get a bit familiar with different parts of the prototype. Then they can start working with different parts as explained in the instruction. We have applied audios in this part, since pupils at this age range are not so fast at reading and they might find reading so boring.

Appendix D: Difficulties Children Face When Learning Multiplications

As it’s been discussed in the introduction, many articles have stated that involving users in the design process is important. Having children involved early in the design process can help us to find out what motivates them and keeps them engaged in the project. So, we used children as well as teachers as native informants in our project. As discussed with some children, we will represent some of the difficulties that children might encounter when learning multiplication and clock reading.

i. Difficulties in learning multiplication

- Learning multiplication is important for children’s mathematical progress in their study. Multiplication facts are mostly about practice, which may get boring for majority of the children and make them discouraged.
- Difficulty in memorizing the basic multiplication facts.
- Among the basic concepts of multiplication, the concept of multiplication as repeated addition was found difficult by most of children.
- Representation array is an efficient way to introduce the concept of multiplication to children.
- Poor instruction and insufficient teaching resources is one of the factors that play a role in children’s low achievement in mathematics.

One of the strategies that pupil use is called “skip counting”, which means counting by the second factor the number of times indicated by the first factor. For example: 4x3 could be found by skip counting 3, 6, 9, 12. Skip counting is one of the beginning steps to learn multiplication. It also helps when learning to read a clock. Having this in mind, we decided to take a new approach in teaching multiplication. In this approach, we have combined two mathematical concepts, multiplication and clock reading. We used clock face to teach timetables. Most of pupils find clock reading a fun and enjoying activity, whereas they have problems with learning multiplication. So, using our application children can learn timetables through manipulating the clock face.

It is proposed that the most effective sequence of instruction for multiplication facts is as follow:

- “Introducing concepts through problem situation and linking new concepts to prior knowledge”
- “Providing concrete experiences and semi-concrete representations prior to purely symbolic notations.”
- “Teaching rules explicitly.”
- “Providing mixed practice.”

### ii. Difficulties in learning time telling:

- The most common error of children in clock reading was misreading the hour, especially when the minute hand was on the left side of the clock.
- Pupils have more difficulty with larger numbers.
- Confusion occurs over the differently named hours for current and “till” times.
- Another difficulty that some children experience is where the short hand is exactly halfway between two hour values.
- Evidence shows that times after half hour would be more difficult than those before the half hour.
- A suggested sequence for instruction in reading time is: hour, half hour, quarter hour, five minute and minute times.
- Interpretation of the numbers is one of the difficulties for children in clock reading. The interpretation of the numbers is different
- Depending on the clock hand that is pointing at them. Each part of the clock face has different interpretation as well.
- The most commonly observed error in children’s clock reading is introduced as ‘selective attention’ that means paying attention to only one hand of the clock.
- Applying a false point of reference is another kind of error that children may experience in clock reading; (e.g., three before quarter to twelve instead of 18 to twelve).
- Mixing up the function of the hour and the minute hand is another type of error (e.g., ten to three instead of quarter past ten).
- Mixing up the terms ‘to’ and ‘past’ (e.g., quarter to ten instead of quarter past ten)