GPS-based Math Trails

A multiple case study on benefits and challenges.

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PREFACE

Writing about a topic that was new to me in my educational culture was challenging. However, the challenge of completing this study has been overcome. This study marks the end of my master's program, mathematics didactics at the mathematics department of University of Agder.

I would like to thank the University of Agder, Kristiansand for the opportunity given me to study. I would like to express my sincere gratitude to my supervisor Pauline Vos for her guidance. Throughout the time of my thesis, she has been very supportive and understanding. I would also like to express my sincere gratitude to my former assistant supervisor, Cengiz Alacacci for his support during and after supervision.

I would like to thank the participants of my participants very much for their time. They were available both for the math trails activities as well as the interviews. This study would not have been possible without the help of my wonderful participants.

I am also thankful to my husband Ebenezer Adu-Darko for the encouragement he gave to me. In my darkest moment of the study, he was always encouraged and gave me the necessary support.

I wish to express my gratitude towards friends who contributed in any way towards the success of my thesis. God bless you all.

Amidst everything, to God be the glory.

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JENNIFER NTIM

ABSTRACT

It is an undeniable fact that mathematics contributes tremendously to human activities. However, some students think of mathematics as boring and unrelated to the environment. Some students have expressed how mathematics is not related to the real world. Some dressed-up tasks which are inauthentic are given to the students as word problems to connect mathematics and reality. This study sought to find an alternative activity to these dressed-up tasks. As well as find the challenges and benefits of having such kind of activities.

Research has shown that, having outdoor learning provides for the students to learn in a real and authentic situation. Some educational theories prove that learning in an authentic situation mediates between students' mathematical knowledge and reality.

Math trail, is an outdoor math activity, in which the participants walk to discover mathematics in the environment. In recent times, math trail activities have been used in schools to supplement mathematics learning. In this study, the math trails activity was blended with modern technology. That is, it was GPS-based. This study sought to find out the benefits and challenges of doing a GPS-based math trail.

Case study and design-based research approaches were employed for the study. Actionbound app was used to design the math trails activity. It had a GPS feature and also a feature which tasks and solutions of tasks could be used. The data were collected from two different groups; 16 first-year videregående students, 10 fourth-year mathematics education teachers, 1 mathematics lecturer and the researcher. Two math trails activities were done namely; the KKG math trail and the pre-service teacher's math trail. One of the major benefits is that the students saw the connection of some mathematical concepts with real life and one of the challenges was when they didn't see some of the tasks relating to mathematics but rather, a question whose answer needed to be guessed while having the activity. The GPS-based app helped the participants to find the tasks locations without difficulty. The Actionbound app which contained tasks and some solutions to the tasks gave immediate feedback to the students.

For the implementation of GPS-based math trails in education settings, further research on this topic is recommended. In the end appendices of the instruments used in the data collection, transcripts, and an information letter are provided.

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CHAPTER 1

1.1 Background of the study

Mathematics as a branch of science has contributed tremendously to human life, from civilization up to this century we are in. Throughout our daily lives, mathematics is used without the users not even realizing they've used mathematics (Kusmaryno, 2014). D'Ambrosio, (2008) mentions that mathematics is the dorsal spine of civilization, which means that mathematics has played a significant role in almost all aspects of the world's activities. OECD (2013) and PISA's (2012) definition of mathematics literacy acknowledges that mathematics literacy helps individuals recognize the role mathematics plays in the world and in helping them make the kinds of well-founded judgements and decisions required of constructive, engaged, and reflective citizens.

However, some students who have experienced mathematics as a school subject speak of its boredom, limited relevance and predictability, and ask when they would ever use the mathematics learned (Webb & Peck, 2020). Magotti (2020) also points out that notwithstanding the benefits derived from learning mathematics, the subject is perceived by most students to be boring, difficult, not practical, abstract, and to easy learn this subject, you must possess special abilities not everyone has. In Magotti's (2020) study, 45.7% of the participants liked mathematics while 54.3% disliked it with reasons given that it is difficult, and much of the mathematics learned is not encountered in their out-of-school life.

Ferri (2018) mentions that teachers claim they have given real-life tasks to students, yet the students still perceive the tasks as irrelevant and meaningless since the students may not really need them in their personal lives or do not see any relation to their lives. However, some research also shows that giving students tasks with authentic, real-life contexts motivates students to like mathematics since they can relate these to their environment. Blum et al. (2007) also mention that word problems allow students to have a feel of the usefulness of mathematics in real life, however, at their worst they are an unrealistic disguise asking for recipe approaches to their solutions. For example, in a math problem like "divide five balloons between two people", the balloons are real and people use them in real life, but it is impossible to divide five balloons evenly among two

people unless one of the balloons is destroyed, or one person gets more than the other. In such tasks, although the question seems to link the mathematical operation of division to a real-life situation, the task is not realistic and does not show any usefulness of mathematics. This is what Vos (2018) describes as dressed-up tasks that lack authenticity. Vos (2018) adds that some tasks may have authentic contexts (e.g., round road signs that really exist), but at the same time a mathematical question (e.g. to calculate the perimeter from a given diameter of the road sign), which makes the task of the type mentioned earlier, a dressed-up task that aims at applying mathematical rules without showing mathematics as being useful to the students.

In this thesis I want to study alternatives to dressed-up word problems, whereby students carry out meaningful mathematical tasks in authentic real-life settings. The aim is to study how such kind of activities can be planned so that students get new experiences and feelings about learning mathematics.

1.2 Statement of the problem

Mathematical modelling is the activity, whereby a real-life problem is solved with the help of mathematics (Ferri, 2018). The inclusion of modelling into mathematics teaching helps students to use the mathematical formulas learned to solve real-world problems or apply them in situations that really exist. Mathematical modelling is one of the competences that many educators and curriculum developers in mathematics education wish students to learn (Ferri, 2018). For example, the German mathematics curriculum has strongly intensified mathematical modelling since the 1980s and it is one of the six general mathematical competencies as of 2016 (Greefrath and Vorhölter, 2016). The Norwegian mathematics curriculum starting from the 2020 academic year also includes modelling as one of the general competencies. Vos (2013) also mentions that in The Netherlands, mathematical modelling is a mandatory competence in the curriculum. Not only these countries but also many other developed and developing countries include modelling into the mathematics curriculum.

In my study, I want to take students outdoors to find authentic contexts, to which I want to offer them meaningful modelling tasks. I aim to do this through *math trails*. A math trail is an outdoor

activity which was introduced in the 1980s (Shoaf, Pollak & Scheinder, 2004). In educational context math trail is an activity, in which students receive tasks outside of the classroom and then use mathematics to address problems to real situations in the environment. Although math trails can make mathematics more real and authentic (Richardson, 2004), and math trail activities are being tried out by students and teachers, most countries have not included math trails in their curricula. . In my study, I want to organize math trails by using a special digital app (Actionbound), see Figure 1 (left). It makes use of GPS for showing the students on their phone where to go for the math trail, see Figure 1 (middle). When they have walked to the location, the app sends them a question that they can answer on their phone, see Figure 1 (right). The Actionbound app mediates the teachers assessing of the math trail by providing the teacher with information about. From Figure 2, overall details such as the time every group starts and end the bound, the score for each group, and the rating of the math trail activity. Actionbound app allows the teacher to see detailed information of the math trail activity by each group. The ratings by each group help the teacher to be informed about how each group feels about the math trail activity. I want to find out how a math trail with a GPS-based app can be organized without any problems faced by the students. My aim is to study possible challenges and benefits for the students and for a teacher using the math trails activity with the GPS-based app. Everything has its positive and negative effects, hence I want to find out the same for math trails.

Figure 1. GPS-based app Actionbound (left) to give directions to a location (middle) and to offer a task and answer options, for example through a slider (right).

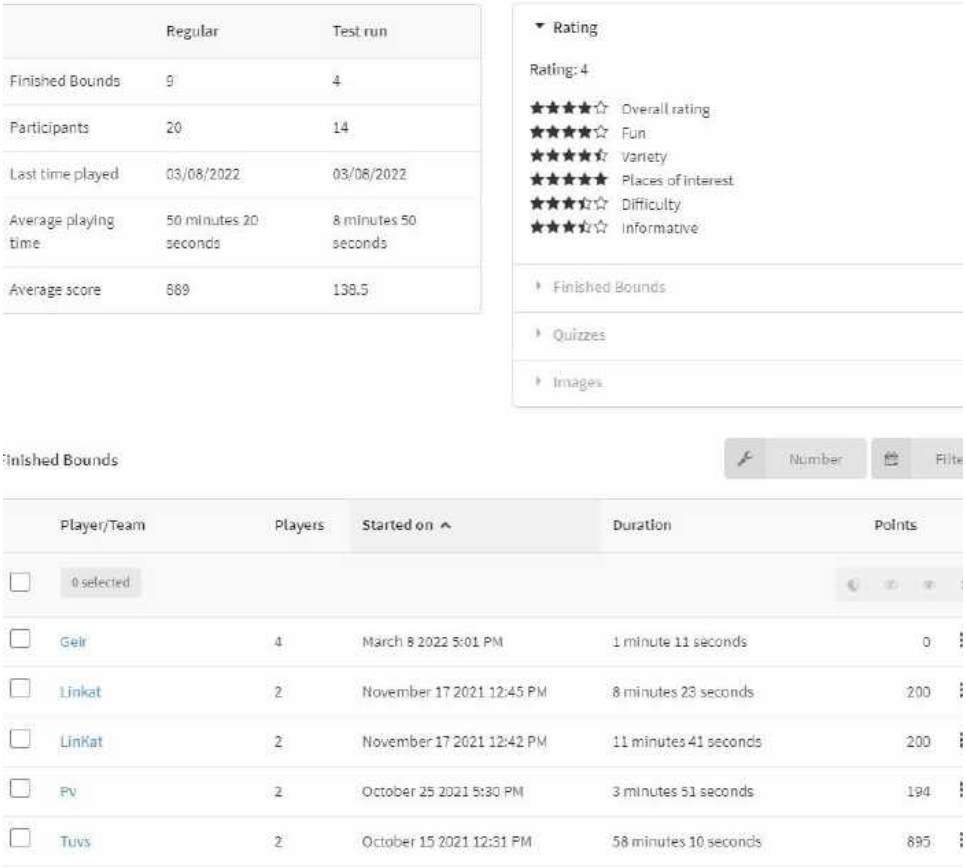

Figure 2. The Actionbound app mediating the teacher's activity by providing a summary of how a math trail went.

1.3 Purpose of the study

In my study, I aim to find benefits and challenges of GPS-based math trails. The benefits and challenges of such math trails activities will be studied from the perspectives of students and teachers.

Math trails take students out of their normal classroom environment, where they navigate from one task location to the other with the help of the GPS-based app. This entails that students need to install the app and that there are tasks for each location. From the students' perspectives, I aim to study how a GPS-based math trail will help the students understand the relationships between mathematics and the environment. The study also aims to find how math trails activities help students to clear some of the misconceptions about the unreality of some mathematics. In addition to the aims stated above, the study seeks to find the positive and negative sides to learning mathematics outside the classroom, and how math trail activities may help students to gain new insights about learning mathematics.

From the teachers' perspective, I aim to study how teaching through math trails activity can help a teacher to gain more experience in connecting mathematics to the real world. Are there benefits and challenges for the teacher, as a planner of a math trail and when implementing it?

When a class of students is taken outside, there are possible challenges that both teachers and students are likely to face. The teacher as planner of the GPS-based math trail will have to consider several factors that make the math trails activity different from 'normal' classroom activities. A teacher who plans to use math trails will have to consider the appropriate teaching and learning tools, since the learning activity is not face to face or at a fixed position. Especially when a math trails activity requires a digital tool, there can occur technological challenges (battery power, internet connectivity, etc.), attention diversion (watching movies, playing games, etc.), and communication issues (e.g., unclarity of the location or the task).

Based on the issues raised in the above paragraphs, this study seeks to find benefits and challenges students encounter while doing a GPS-based math trail. In addition, this study will also look at the benefits and challenges teachers encounter while planning and applying a GPS-based math trail.

1.4 Research questions

This study seeks to answer the questions

1. What are challenges students face when doing a GPS-based math trail?
2. How do GPS-based math trails activities benefit students?

3. What are possible challenges teachers face when planning and implementing GPS-based math trails activities?
4. What are benefits teachers derive when planning and implementing GPS-based math trails activities?

1.5 Motivation of the study

There have been times I had asked myself as a mathematics teacher and a mathematics student what are the importance of some the mathematics we learnt at school. There have been times I felt like knowing how to do simple arithmetic operations is simple. There have also been times I questioned myself about the word problems I solved in class. I asked myself, can we not practice mathematics? Is mathematics only in the book and not applicable in the environment?

When the topic of math trails was introduced to me in class by Pauline Vos, I became interested. I said to myself, "this is the time to experience mathematics in reality". I began the research because it was connected to the practicality of teaching and learning mathematics.

I chose the math trail concept because, in my opinion as a mathematics teacher, it might help me gain experience in bridging the gap between classroom mathematics and reality. I also aim for this study to help answer some of the why do we study mathematics questions asked by students sometimes.

1.6 Significance of the study

Math trail is an activity which was discovered in the 1980's. Shoaf et al (2004) wrote about math trails without GPS. In recent times, Ludwig and Jesberg (2015) and Gurjanow and Ludwig (2017) have merged math trails with mobile learning. In this mergence, the math trails are designed on mobile apps with GPS instalment. With the help of the mobile app, a math trail activity can be in the form of a game (gamified), GPS guide integrated in the app guides the participants to the trail to the desired location.

Although several authors have written about the benefits and challenges of having outdoor learning as well as mobile learning, few studies have been carried out on benefits and challenges of GPS-based math trails. My study aims to help teachers and GPS-based math trail developers to know about possible challenges participants and teachers can face. Thereby, reducing these challenges to have a smooth math trail. This study aims also to help identify possible benefits of math trails.

This study aims at helping teachers to find alternatives for dressed-up tasks, and also at helping students to connect mathematics to the real world.

In any master's study, the scope of the study has to be limited. I chose to focus on benefits and challenges for teachers and students, since the study then will offer practical recommendations. It means that there are other aspects related to math trails that I cannot include. For example, I will not study how to utilize math trail as a form of assessing the students or as a diagnostic teaching method as suggested by Buchholtz (2017). Also, I did not intend to study how students solved the tasks mathematically and analyze correctness of answers after the math trails. Instead, I aimed at the participants' perceptions of the benefits and challenges.

At the start of my study, I aimed at connecting with two educational institutes in Kristiansand to implement one math trail at each of them. As an international student from Ghana studying at UiA in Norway, I did not intend to disturb the existing teaching for more than one double lesson. Consequently, I could not carry out a series of several math trails with the same participants to study the effects of math trails on students' learning in the long term. Also, I did not master the Norwegian language and needed to connect with teachers who taught mathematics to their students in English. Therefore, the selection of participants and the focus of the study was adapted to the circumstances.

1.7 Structure of the study

This thesis is divided into 8 chapters. Chapter 1 contains the background of the study.
Chapter 2 discusses both theories and empirical studies.
Chapter 3 contains the research approaches and methods used in the collection of the data as well as a description of the participants and instruments used and a report of the pilot study.
Chapter 4 gives a report on the first math trail case study.
Chapter 5 gives a report on the second math trail case study.
Chapter 6 discusses the analyses of chapters 5 and 6.
Chapter 7 presents the conclusion of the study and offers recommendations for its implementation in schools.

CHAPTER 2

Theoretical framework and Literature Review

This chapter gives the theoretical background for the study. It is presented from generalization of issues to specification of issues. This chapter also reviews some empirical research related to the study. The main aspects that will be looked at in this theoretical chapter are socio-cultural theory and situated learning theory with regards to outdoor learning activities. For reviews of empirical studies, the areas that will be looked at are mobile learning, math trails, and a perspective on challenges and benefits.

2.1 Socio-cultural theory

2.1.0 Introduction to socio-cultural theory

The socio-cultural perspective on cognitive development theorized by Lev Vygotsky was based on the cognitive development of children. The main assertion of this theory is that cognitive development in early childhood is influenced, or advanced by social interactions specifically with those who are more skilled than the learner, and these social interactions are fundamental to the cognitive development of the learner. According to Scott and Palinsca (2013), sociocultural theory explains how individual mental functioning is related to cultural, institutional and historical context. Due to the relations with others, the psychological development of the learner is influenced by social interactions with people and culturally organized activities. According to Guerrero Nieto (2007), sociocultural theory highlights the relationship between social and individual processes in the co-construction of knowledge.

Vygotsky in his theory suggested two lines for the beginning of human mental activity which are: the natural line and the social or cultural line. The natural line enables basic functions, whereas the social line is active in the genesis of higher mental functions. The natural line is where all human mental activity begins and acts as the foundation on which the higher mental functions are built. Vygotsky highlighted that, although the natural line precedes the social line, both lines of mental activity are intertwined and they come together to produce the specific nature of human consciousness (Hasan, 2005).

In sociocultural theory, there are two major themes which are: culture-specific tools (language, artefacts, etc.), and the Zone of Proximal Development (ZPD).

2.1.1 Mediation by culture-specific tools

According to the Oxford Dictionary, to 'mediate' means to intervene in a dispute in order to bring an agreement or reconciliation. The Cambridge Dictionary defines 'mediating' as talking to two separate people or groups involved in a disagreement to help them find solutions to their problems. In socio-cultural theory, Guerrero Nieto (2007) defines mediation of the mind as a state, in which an individual does not establish a direct relationship with the world, but that this individual relationship with the world is mediated through the use of tools. Taber (2020) states that the purpose of mediation is to allow what would otherwise be impossible. Research has shown that ZPD and peer interaction play a role in Second Language Acquisition (SLA), which are interconnected and fall under the umbrella term of mediation (Guerrero Nieto, 2007).

In socio-cultural theory, tools shape the ways in which humans interact with reality (Cook, 2010). Tool mediation is a term which was coined by Lev Vygotsky, by which he asserted that these mediation tools act as agents. Vygotsky further provided a definition for culture specific tools which served as an intervening link to consciousness. These tools can be signs and symbols, language, etc. (Cook, 2011). Baker (2010) agrees with Cook (2011) by saying that tools include artefacts such as hammers or stepladders, but they also can be tokens and other signs and symbols. Kozulin (2003) mentions what is called psychological tools. Psychological tools are symbolic artefact such as signs, symbols, texts, or formulae. When the utilization of these tools are mastered by the individual, the individual gets control over their own natural psychological functions of memory, perception, attention etc. Kozulin (2003) makes clear that every culture has its own set of psychological tools, which can be used in appropriate situations. For example, a math trails activity can be a tool that helps students and pupils to see the connections between mathematics and the real world, however, this same tool may not work in an English language setting. The core of cognitive education lies within the provision of students with new psychological tools that can shape either their general or more domain-specific cognitive functions.

Hasan (2005) mentions how tools are important in the mediation process. The tools used in the mediation process are artificial stimuli because they were not created naturally but rather came into existence as a result of social life. Without mediation tools, certain mental activities would not be possible. The sociocultural theory of Vygotsky specifies that the development of a child's higher mental processing depends on the presence of mediating agents (Kozulin, 2003).

Further research into Vygotsky's theory showed that there were three types of mediation through tools; mediation through psychological tools, mediation through human beings and mediation in the form of organized learning activities (Kozulin, 2003). Agents that facilitate the process of mediation are, for example, teachers, peers, and technology. The human mediator usually tries to answer the question, "what kind of adult involvement in enhancing the child's performance is effective?" (Guerrero Nieto, 2007).

As mentioned above, there are different kinds of tools and several examples of these tools. However, the chosen tools that are being used to mediate learning are influenced by the society and culture in which the learners find themselves. Robbins (2005) explains that our exposure to the way of life determines which tools to use. A person living in a remote area will choose a map on paper as compared to a person living in a city with a mobile phone and internet access, will choose a GPS. In this example, both a map on paper and a GPS are tools, however, a person will choose one of these depending on the location or situation they find themselves in.

Examples of culture–specific tools include language, different kinds of numbering and counting, writing schemes, diagrams, maps and all sorts of signs.

2.1.2 Math trail as a mediating tool

The main role of a mathematics teacher is to make mathematical knowledge accessible to his or her students such that they can apply it in their lives whenever necessary. To make mathematics learning easier, teachers use tools to achieve that, such as psychological tools (tasks, quizzes, etc), and artefacts (textbooks, chalk boards, manipulatives, etc.) (Maffia & Mariotti, 2018).

Hasan (2005) mentions some aspects of mediation that needs to be looked at when planning mediating activities. These are: the mediator, what is being mediated, the mediatee and the

circumstance for mediation. Below, these are further explained in relation to the math trails activity.

A mediator is someone who mediates. The mediator can be either a human or an activity. In this study, the researcher and the math trails activities are both the mediators. The researcher mediates, by planning the activity and by explaining to the students the purpose of the activity and how the activity is going to help them as students. The math trail activity, on the other hand, will mediate between the students' mathematical concepts learned in the classroom and how these mathematical concepts are related to the world by sending them to specific task locations where they solve some real-world problems using the mathematics concepts learned. Also the GPS-based app is a mediator.

What is being mediated? The things or objects that are mediated are the mathematical concepts that students have learnt. These concepts are released and used during the activity. The mediatee are the students to whom the mediation process is going to make a difference in their understanding of how the mathematics learnt learned in the classroom applies in the society or environment in which they live.

The circumstance for mediation is the environment in which mediation occurs. It embraces the location of the mediating activity, in the study it was the school environment, to which mathematical concepts under consideration were used. The circumstances for mediation also embrace the organization of students in groups and a teacher who refrains from giving the answers to the tasks.

2.1.3 The GPS-based app Actionbound as a mediating tool for directing a math trail

Huong and Hung (2021) define mediation as a process in which individual's experience is found through the experience of others. In education, mediation occurs with semiotic tools or cultural artefacts. That is, learning is mediated when learner's psychological processes are generated through interactions with others and the use of tools (Huong & Hung,2021).

Tools such as books and computers help mediate the learners' learning process, in the same way, tools such as computers, books, mobile apps etc. mediates teachers' preparation for a lesson. Tools mediate teachers' delivery of lessons such as the reading of books and online materials to find examples and the appropriate pedagogical methods to use in the delivery of lessons.

In a mobile, GPS-based math trail, the mobile app is the channel through which the participants receive essential information from the designer of the math trail. This information is needed to find the locations and to do the tasks. Thus, the app mediates the finding of locations, and the tasks to be solved, and the ways that participants can answer to the tasks. For example, the app will ask them to do multiple-choice tasks, to write a solutions into the app, or to upload pictures of solutions into the app.

For a teacher who designs a math trail, the mobile app mediates the planning of the math trail. Through the software to design the math trail, the teacher-designer can offer the participants a fixed route (participants have to go from one location to another) or a flexible route (participants cab chose themselves in which order they go to the locations). Also, the teacher-designer can chose to design several tasks at one location, or allow participants to only do a few of the tasks. The app allows the teacher-designer to apply different task formats, such as multiple-choice tasks, text-tasks (participants type their answers into the app) or tasks where participants take a photo of their answer and upload it. Finally, the app allows the teacher-designer to frame the mode of answers to enter (e.g. decimals, range, multiple choices etc.). In summary, the app as a design tool mediates the planning of a math trail.

2.1.4 Zone of proximal development (ZPD)

As stated earlier, there are humans who mediate the learning process known as the more knowledgeable other (MKO) in the concept of ZPD. The zone of proximal development determines what a student is capable of learning on his own and what he is capable of doing with the help of other people that is the MKO. The MKO can be a teacher, peers or any other person who is capable of helping the learner get understand the concept or skill that is being needed (Smagorinsky, 2018). As the learner interacts with the MKO, they learn new things from them which helps them shape their understanding and clear their misconceptions.

Abtahi et al. (2017) claim that tools can also be classified as MKO since they guide or help the learner understand better what they are learning. Hence, when a learner uses a tool, indirectly, the learner is being helped by the tool to appropriate knowledge. They term this as a "multi-directional character of the ZPD among a child, an adult and a tool". It can be said therefore that the ZPD being considered in this study is multi-dimensional, because there is the researcher and a mobile

phone app mediating the students understanding and connection between the mathematics learnt in the class and its application in the outside of the classroom environment.

2.2 Situated learning theory (SLT)

2.2.1 Introduction to Situated learning theory (SLT)

SLT proposed by Lave and Wenger (1991) claims that learning is not achievable when separated from the context in which the learning occurs. The main assumption of SLT is that learning must be learnt in an authentic context that is where the knowledge obtained might be used and knowledge must be learned when authentic activity is involved (Besar, 2018). The SLT is a learning theory which characterizes learning as being embedded in everyday activity, context, culture, fundamentally social, unintentional, and progressive in relation to the learner's participation. The SLT provides options for conceptualizing the studying learning processes outside the classroom (O'Brien & Battista, 2020). The situated learning theory is based on the claim that learners learn in the type of situation where the knowledge appropriated is deployed. That is learning through goal-directed activity situated in circumstances which are authentic and related to the intended application of the learnt knowledge (Billett, 1996). In situated learning theory, the learner cannot be separated from the known. This means that the individual, his context and his activity in the environment should mutually constitute each other (Rambusch, 2006).

In the context of mathematics, Cobb and Bowers (1999) view situated learning theory as a relation of classroom or school mathematics with activities in out-of-school. The purpose of this comparison is to identify the forms of reasoning that arise in the context of different practices or situations. An example they gave in their article is 'learning mathematics as an end in itself in school versus doing arithmetical calculations while selling candies on the street in order to survive economically. Fox (1997), sees the situated learning theory as distinct because it perceives learning to be socially relational rather than a mental process. He argues that SLT does not consider learning as a process of mental acquisition to be a problem. In SLT, the mind is not a container waiting to be filled but rather a mind –in-action in the everyday world. Creating knowledge and learning simultaneously in interaction with the social and material aspects of the live-in-world is a contrast

to the banking model of education which view the minds of learners as an empty container waiting to be filled by the teacher (Fox, 1997).

2.2.2 Outdoor learning as situated learning

Mann et al. (2021) define outdoor learning as "taking students outdoors into their immediate or nearby surroundings to learn essential lessons of the curriculum with four possible zones which are; school grounds, local neighborhoods, day excursions and overnight stays or residential camps and expeditions". Outdoor learning or outdoor education is being employed in several learning subjects such as history (Harris & Bilton, 2019), physical education (Sutherland & Legge, 2016), Science (Rois & Brewer, 2014), mathematics (Sollervall et al. 2012) etc. Outdoor makes for a different learning situation than school – feel, students learn with their senses (feel, touch, smell, etc), the teacher is not in front of the whole class, and students can have more agency, in outdoor learning situations.

In this study, outdoor learning is associated with situated learning because it provides the opportunity for students to learn in a situation which is authentic and have a different feeling as compared to working with examples in the classroom.

The government t of UK has recognized the importance of learning outside the classroom after a period of concentration had improved narrowly-defined standards, through didactic teaching methods (Waite, 2017). Findings from the State Education and Environment Roundtable has shown that outdoor education is associated with improved outcomes on standardized test in mathematics (Harris & Bilton, 2019). Outdoor learning offers possible means of making abstract subjects concrete. Quibell et al. (2017) in their experimental study confirms that students who participated in outdoor learning program increased their attainment in English and math as compared to students who received conventional classroom-based schooling.

When it comes to the health and physical well-being of pupils and students, physical activities cannot be exempted, hence the need for active learning through outdoor learning. Outdoor learning enhances the student's ability to concentrate as well protecting them from falling ill frequently. Research has proven that preschoolers who are allowed to spend time in a natural area on daily basis have improved physical fitness, motor skills and coordination skills and a higher ability to concentrate on the rest of the activities in the classroom (Mygind, 2007). Marchant et al. (2019) also agrees that there is a positive relationship between the health, well-being and educational

attainment of children and that the healthier and happier a child, the more the child achieves higher educational attainment. Marchant et Al. (2019) see outdoor learning as a pedagogical approach, which can be used to enrich learning enhance school engagement as well as improve the well-being of students.

An Ohio initiative encourages educators to use the land around their schools to engage students in their learning in order for them to explore and understand the ecosystem. When students experience the outside world, it gives them the opportunity to gain knowledge in different ways (Pfouts & Schultz, 2003).

Richardson (2004) identifies one of the uses of math trail as a support for teaching. When you are teaching a particular topic, you can select one or two sites where you can design problems related to the topic you are teaching, where students have problem solving authentic problems in mathematics. In the case of young kids, you will have to find an aide, be it a teacher or parent to do the specific activities.

In as much as outdoor learning has benefits, it also has its challenges. Research has shown that outdoor learning activities tend to decline as pupils move from early years to later stages of primary education. Waite (2009) mentioned that one the reasons for the decline in outdoor learning could be as a result of pressure created by the national curriculum. Waite (2009) clarified that testing or practicing of core subject in the national curriculum creates pressure on the broader curriculum for schools. Other difficulties associated with outdoor learning were: money, time, and the nature of the outdoor space available.

Oberle et al. (2021) mentions that several studies conducted in Europe have identified barriers to outdoor learning at school. The barriers to the outdoor learning considered both teacher and systemic levels. It was identified that teachers feeling unprepared and lacking confidence to teach outdoors, lack of support, funding and resources, feeling constrained by a traditional view of teaching, and inflexible daily teaching schedules were barriers to outdoor learning. For example, the lack of confidence and feeling constrained by traditional view of teaching was a result of teachers' training and professional development that neglected outdoor learning. Waite (2020) also agrees with Oberle et al. (2021) staff uncertainty about linking outdoor learning to the curriculum was a barrier. However, Waite (2020) was uncertain as to whether this was as a result of pressure

on the delivery of the curriculum such that teachers could not get enough time to prepare to become equipped and capable of providing quality outdoor learning.

Humberstone and Stan (2011) claims that not all outdoor learning experiences are beneficial. The claim was based on the reason that, informal and formal education that takes place depends on the how the teacher interacts with the students. That is, the way a teacher teaches in class has a relation with the quality of outdoor activies planned by the teacher.

2.3 Mobile learning

O'Mailley et al. (2005) describe mobile learning as learning which is done through wireless mobile devices such as mobile phones, personal digital assistants, laptops etc. They further explain that, if the learning should take place in a fixed or predetermined location like the classroom, home, office etc., then it ceases to be mobile learning. If the learning is away from the usual environment, then it is mobile learning. Also, even if the learning environment is a usual environment but mobile, then it is mobile learning.

Sharples et al. (2005) in postulating mobile learning theory mentioned the features that a mobile learning must have. According to Sharples et al. (2005), the features that mobile learning must have are; it is organized outside of the classroom setting, learners must not be at a fixed location during mobile learning, mobility is key to mobile learning, it should cover both formal and informal learning, it should theorise learning as a constructive and social process, and the last but not least, when planning mobile learning mediated by technology. The designer of the mobile learning activity should check that the availability of such technologies is considered.

Sharples et al. (2009) list some suggestions made by other researchers that when planning a mobile learning activity. Research suggested that when designing mobile learning activity, the designer has to; Create quick and simple interactions, prepare flexible materials that can be accessed across contexts, consider special affordances of mobile that might add to learner experience (e.g. the use of audio or user anonymity) and use mobile facilities not only to deliver learning but also facilitate it making use of the facilities in current mobile devices for voice communication, note taking, photography and time management.

Sharples et al. (2009) in the same article mentioned in the previous paragraph added that, when planning a mobile learning activity, it should be driven by a specific learning objective. They further explain that the use of technology should not be the focus but rather the mobile learning activity as a facilitator (pp 233-249). For example, in this study, the focus of the math trail activity is not centered on whether the students will be able to use the Actionbound well or not, or students getting points for answering a question, but rather, the focus of the math trails activity is centered on how well students connect mathematics models to real life situations. That is, the use of technology is important for the enhancement of mobile GPS-based math trails, but should not have the main focus.

2.4 Math trails

2.4.1 A historical perspective on Math Trails

Shoaf, Pollak and Scheinder (2004) define math trail as a walk to discover mathematics. English et al. (2010) also define math trails as a way of promoting mathematics learning by assigning meaningful real task to students outside of the classroom, with a sequence of designated sites along a planned route where students explore math in the environment. Richardson (2004) also define math trails as a sequence of stops along a route, which has been pre-planned alongside with some mathematical task where students examine mathematics in the environment.

Math trails first appeared in England and Australia in the 1985. They were used as a holiday activity for families and the mathematical ideas that were included in the trail were; discovering the invariance of pi (investigating a circular pattern of bricks in the pavement), estimations, counting and patterns that is series and sequence (Shoaf et al., 2004). Shoaf et al. (2004) give some characteristics a math trail should have; these are:

- math trails are for everyone: most people have studied math and everyone uses math, hence, math trail problems should be designed in such a way that it is interesting and accessible to people. To ensure this, there should be a blend of easy and hard problems with the purpose being that, at least everyone will feel the accomplishment of contributing to problem solving.
- math trails are self-directed

- math trails are cooperative and not competitive: the purpose of a math trail activity is to bring attention to how the problems are solved and not necessarily finding single correct solutions. A single person can choose to have a math trail alone, however, math trail is family and group oriented.

- math trails are voluntary: you are not obliged to complete the math trail at a goal, but if you need some breaks in between, you can take them and continue the math trail later on.

- math trails are opportunistic: we believe that" math is everywhere", therefore you have to take advantage of your locale. Any public place that allows safe walking is ripe with math problems for an imaginative trailblazer.

- math trails are temporary: places change therefore, permanent trails require maintenance and continuing time and energy and perhaps miss new opportunities.

When designing a math trail activity, the fun aspect should be considered. It should be fun for participants and to ensure this, there are certain factors that you have to consider according Shoaf et al. (2004). These are: location, length of the math trail activity, trail guide and mathematics. To make sure that a math trail activity is run smoothly, you have to consider these; participants, sponsorship, evaluation and history. Shoaf et al. (2004) also outline materials that the participants should be provided with or have with them. Unlike Shoaf et al. (2004) who see math trail as just an outdoor fun activity for families who enjoys the walk without realizing that they are doing mathematics, Richardson (2004) uses it as an educational tool to make learners do hands on tasks while applying the mathematical knowledge gained in the classroom.

Shoaf et al. (2004) describes that the designer of the math trails had to design maps including its scale, appropriate landmarks and features as well as clear notations to the locations for the activities. Regarding the mathematics questions to be used, the designer of the math trails had to organize them on the site map. This meant that the math questions were hand written on the map or printed on the map. However, we are in the era of digital, mobile technology where finding locations is quite easy with the help of GPS. Most phones have GPS already installed in them which helps users get to their locations. In this study, the students will not be guided by a map on paper but rather a GPS installed in an app called Actionbound. As contrasted to the type of location guide used, this study seeks to find the challenges and benefits of doing a GPS-based math trails.

2.4.2 GPS-based math trails

As math trail involves locations which need to be found by the participants, giving them a guide to the location is essential. To enhance math trail activities, digital services like smartphones, tablets or google maps can be used. When you put several mathematical tasks in a mobile device app which has an in-built map that can lead them to different locations, the math trail is called a mobile math trail (Buchholtz, 2020).

Gurjanow and Ludwig (2017) conducted a study on GPS-based mobile math trails. In their study, the mobile math trails activity is gamified in the app. That is, points are awarded with priorities on which of the participants is first or last. To help find the tasks' locations, the MathCityMap (MCM) app was used. This app is similar to Actionbound and has already installed GPS to guide the users. If a user downloads a trail on the MCM app, the user can use the trail without internet connection. This means the user will be able to use the GPS without internet connection. In this study conducted by Gurjanow and Ludwig (2017), instances such as the students having difficulties using the GPS without internet was not mentioned. The purpose of the research was to find out whether a leaderboard (the ranking of who becomes first or last) and game points impacted the students' intrinsic motivation while walking a math trail using the MCM app. In this thesis, I will not focus on leaderboards and game points, but rather how can this math trail activity influence students understanding of mathematics. Much emphasis will be put on how students and teachers benefit from the math trails activities as well as the challenges they will face while carrying out math trail activity. The Actionbound app differs from the MCM app. The math trail can be organized without internet when downloaded, however, the GPS guide cannot direct the participants to the task locations unless there is internet connection. Can this affect the math trail activity by posing some challenges to the students? This research seeks to find challenges and benefits for teachers and students.

Ludwig and Jesberg (2015) also used the MathCityMap app in another study, namely on independent problem solving. In case students could not give the right answer, hints were given. Also, after giving an incorrect answer, the app could tell students the right answer. The provision of hints and telling of the right answer is to serve as a help and replacement for a teachers since a

teacher cannot be present with all groups at the same time during a math trail activity. All answers provided by the participants of a trail were stored in the MCM and could be seen by the teacher. Comparing the features of this MCM app to the Actionbound app, a teacher cannot directly see the answers a student or group in puts unless the teacher asks the students to upload pictures of their solution into the Actionbound app. However, the teacher can see the names of the participants, the date and duration of the math trail, the actual scores and percentage scores, the number of quizzes solved, the percentage of quizzes solved, and the number of spots found together with its percentage. Unlike the MCM app, the Actionbound does not allow for the input of decimals. That is, the solutions written in Actionbound are rounded to the nearest whole number. Can such kind of constraint prevent students from having a smooth math trail, and may be one of the challenges to be studied.

Buchholtz, (2017) mentions that students are mostly subjected to difficulties anytime they are faced with real world problems relating to mathematics hence the need for the writing of his article "how teachers can promote mathematising by means of Mathematical City walks." He suggests that to promote math trails the teacher has to consider tasks that are relevant to the cognitive demands of the pupils, relevant previous knowledge of the pupils, and in relation to topics taught in class. Buchholtz (2017) did research with 25 seventh grade pupils from the Hamburg Gymnasium who didn't have much experience in mathematical modelling. Students took with them concrete materials which were needed for the task. The tasks were divided into sub-tasks which made the processing time for students quite short. 90 minutes were used in total for the math trail, with processing time being 20 minutes for each task. The results showed that for pupils who had difficulties undertaking the tasks, the researcher encouraged using a diagnostic teaching method. He mentions some characteristics that a math walk should have and how to use the task diagnostically to help students come with the solutions themselves. He recommends that teachers should incorporate math trails in teaching for students to mathematize real world problems autonomously. I learnt from this research that tasks can take up to 90 minutes, but that students' autonomy is an important aspect in math trails.

2.5 Benefits

The online Merriam-Webster dictionary (1828) defines benefits as something that produces positive results or that promotes well-being. According to the same dictionary, benefits can be

explained as a financial help in time of sickness, old age, or unemployment. Lots of researches have been conducted in different areas looking at its benefits.

However, in this study, the benefits that is being looked at is the positive feedback that the participants of math trail activity will derive. That is how helpful the math trail activity was to them.

Fägerstam and Grotherus (2018) in their study to find out about secondary school students' experience of outdoor learning found that outdoor learning facilitated student centered and cooperative learning. Asabere (2013) lists some benefits of mobile learning which are: it facilitates collaboration among students, it provides opportunity for students and to learn while moving, mobile learning can occur at anytime, anywhere and content can be accessible anywhere. These statements on mobile learning occurring anywhere and anytime contradict Waite's (2009) statement that outdoor learning puts pressure on the curriculum as a result of time and that teachers lack skills to implement such activities. Therefore, I studied challenges and benefits, without assuming that mobile math trails can be organized at anytime and for any level of education without constraints.

Mehta (2016) in his article list some benefits of having mobile learning which are;

- Mobile devices can be used anywhere, anytime, including at home, on the train, in hotels this is invaluable for work-based training.

- Each student can learn at his or her own pace - some student may be slower learners. The students who pick up things fast need not waste time going repeatedly through basic lessons.

- Interaction with fellow students and instructors will be a great help. It is an accepted fact that learning is made easier when information is shared, and questions are answered through a sort of combined study. This helps several students to work together on assignments even while remaining at far-flung locations.

Meaningful learning is one of the expected benefits for this math trail activity. Vallori (2014) mentions that meaningful learning occurs when humans relate new concepts to pre-existing familiar concepts and this is very useful because it enables real learning, it generates greater retention and facilitates transferences to other real situations. In my study, I will study challenges

and benefits of math trails and it could be a benefit if the activity helps students to learn at their own pace as well as help improve interactions with fellow students and teachers.

2.6 Challenges

One of the objectives of this thesis is to identify the possible challenges that students will face when participating in a math trail activity. The term challenges has several meanings according to the Cambridge and Webster online dictionaries. However, in this work, the challenges that are being looked at refer to difficulties, constraints, limitations or hurdles students and teachers will face while doing the math trails activity. First, are there challenges that the students encountered while having the math trail activity. Also, the challenge will also be looking at anything the students and teacher wanted to achieve but they couldn't do during the activity. That is anything that constrained the participants and the teacher from being able to have a smooth math trail.

Looking at the challenges that participants or planners of outdoor learning encounter, Davis and Hamilton (2018) in their article which examined the challenges of assessing early year's outdoor classroom identified that, lack of appropriate resources, level of staff expertise, child-staff ratio, adverse weather, and changes to curriculum policy which place emphasis on the formal assessment of children where the challenges that they found in their study. Davis and Hamilton (2018) agree with Waite (2009) that the level of expertise of teachers can be a challenge for organizing outdoor activities such as mobile math trails. Therefore, I studied the benefits and challenges of GPS-based math trails not just from the students' perspective, but also from a teacher perspective.

Edward-Jones et al (2018) in their study to find out the challenges of learning in a natural environment identified that one of the challenges teachers faced when planning outdoor lessons was finding out which activities are best suitable for classroom and which will be the best to have outside, of which led to the participants suggesting that, giving teachers training on how to help teachers to become well equipped and also boost their confidence in taking the children out and also give them inspiration for integrating learning in the natural environment when planning lessons. This is a point that fits my study on challenges and benefits.

Williams and Scott (2019) in their study of exploring the benefits and setbacks of outdoor learning in a U.K secondary school found that risk management, weather, time, flexibility, etc. as some of

the setbacks of having an outdoor learning. Due to the inflexible nature of the curriculum, time becomes an issue for having mathematics outdoor learning activities. They further recommended that students' motivation as an obstacle to having outdoor mathematical activities be looked at in future research. These were points that I had to consider as well.

Mehdipou and Zerehkafi (2013) conducted research about the challenges of mobile learning. In their study they categorized the challenges of mobile learning into technical challenges and social and educational challenges. Some of the technical challenges found were internet connectivity, battery life, screen size and key size. For the social and educational difficulties, some of the difficulties listed were accessibility and cost barriers for participants, how to support learning across many contexts, frequent differences between device models, technologies and functionality, developing appropriate theory of learning for the mobile age, etc. Mehdipou and Zerehkafi (2013) further mentioned that, in addition to the numerous challenges was the cost associated with equipment, connectivity, maintenance, technical support and training of teachers. Fägerstam and Grotherus (2018) listed some disadvantages of mobile learning which included it may give students the opportunity to cheat. As suggested earlier by Sharples et al. (2009), the focus in my research will not primarily be on the technological aspects but rather on the math concepts involved. However, technological challenges as mentioned in the studies above will still be present because the digital GPS-based app mediates the math trail activities in my research.

Mehta (2016) in his paper lists some challenges for mobile learning in education, as well the disadvantages of mobile learning. Among the challenges for mobile learning in education were;

- Negative Implications: Some mobile devices may contribute to unethical behavior by students or distraction in the classroom. Mobile devices may also compromise the physical health and privacy of students.
- Limitations: Some mobile technologies feature poor designs with usage limitations that may adversely affect learning.
- Theory backing mobile learning.

Baased on the rich literature described above, this study will focus on the benefits and challenges of GPS-based math trails mentioned as well intending to reveal other benefits and challenges that will be encountered by students and teachers.

CHAPTER 3

Methodology

This chapter looks at the research approaches, methods and ethics for the data collections in the study. The chapter also looks at the participants, research instruments and the pilot study.

3.1 Research Paradigm

3.1.1 Philosophical underpinnings

All research is based on key philosophical assumptions regarding the nature of the research, and how evidence for finding answers to the research questions is supported by the methods used in the research. The assumptions can be distinguished between those regarding what 'knowledge' entails (ontology) and those regarding how the knowledge is established (epistemology) It is advised for researchers to be explicit about these assumptions (Alharahsheh & Pius, 2020).

My research on GPS-based math trails and how teachers and students experienced benefits and challenges cannot be detached from myself. I was not an external observer, but I was simultaneously researcher and designer of the math trail activities and thus a participant-teacher. Also, I interviewed participants for their evaluation of math trails that I had designed myself. which meant that they possible were politer to me than to an independent interviewer. And finally, as a researcher, I interpreted and analyzed the interviews about 'my' math trails, which may put a bias in the analysis. Because of these complexities of my roles in the research, this study is based on the ontological position called constructionism. The constructionist positions challenge the opinion that organization and culture are pre-given, therefore, social actors as external realities that have no role in influencing (Bryman, 2016). In other words, this constructionist position accepts that social actors influence culture and organizations. The epistemological position for this study is interpretive, which means that the collected data will not be 'objective' but need interpretations to make meaning of them.

A paradigm is built on an ontology and an epistemology. This study was carried out within the interpretivism paradigm of research. Bryman (2016) defines interpretivism as a type of research in which the strategy of the research is designed to grasp the subjective meaning of social actions. Interpretivism as opposed to objectivism focuses on the subjective views of the study's participants. Interpretivist are of the view that people give meaning to their social world, therefore, researchers seek to investigate how humans perceive and make sense of this world. This means

that interpretivist researchers usually dwell on the experiences, understanding and perceptions of individuals rather than relying on numbers of statistics (Thanh & Thanh, 2015). In an interpretivist paradigm, the researcher interprets his or her thoughts based on the views of participants. This results in an analysis of the data that is subjected to the views of both the researcher and participants.

The interpretivist paradigm is well-suited for researchers like me, who play multiple roles in the research, namely as teacher organizing the GPS-based math trails and as a researcher studying the benefits and challenges of these. Below, I will further explain my personal involvement in this study, whereby my role as researcher cannot be detached from me being simultaneously a participating teacher in this project. The explicit awareness of the research paradigm should assist in navigating the subjectivity elements that come with this type of research,

3.2 Research design - a multiple case study

Kirshenblatt-Gimblett (2006) defines a research design as the overall strategies that a researcher decides to use to answer his or her research question. The strategies include the design, collection and analysis of data and these are determined by the kind of research problem addressed. Sileyew (2019) states that the purpose of a research design is to provide an appropriate framework for a study and adds that before choosing a research design one has to take note of the approach to be used. Bryman (2016) also gives a similar purpose for a research design in that it provides a framework for the collection of data and data analysis. Case study is one of the approaches in interpretivist studies. The case study approach aims to gain depth in one area as opposed to the shallower breadth obtained through the use of surveys (Phothongsunan, 2010).

The research design in my study is known as case study. Bryman (2016) mentions that a case study helps in having a detailed and intensive analysis of a single case. Also, Suryani (2008) mentions that a benefit of case studies is that they offer larger details about a particular phenomenon. The case study approach provides an opportunity for the readers to obtain other peoples' naturalistic generalizations from personal experience which helps in understanding their social experience.

Guetterman and Fetters (2018) explain the types of case studies that exist and make it clear that the number of cases determines what type of case study it will be. According to Guetterman and

Fetters (2018), the types of case studies are single case studies and multiple case studies. In a single case study, the researcher selects a relevant unusual cases, revelatory cases etc. while in a multiple case study, the researcher selects several cases to compare and contrast. In my research, I used the case study approach because it gives the opportunity for a researcher to study an aspect of a problem in depth (Bell & Waters, 2018). In addition, I wished to strengthen the reliability of the study, and therefore organized two cases so these could be compared. This aimed at identifying in depth, the benefits and challenges of organizing mobile GPS-based math trails. With two cases, my research is a *multiple-case study*. A multiple case study caters for the weaknesses in an interpretivist paradigm, namely that an individual case cannot generate general knowledge of a phenomenon.

According to Suryani (2008), the case study approach has its limitations which include, among others, that it doesn't follow systematic procedures. The findings and conclusions of case studies can be biased because they are based on the views and opinions of the researcher and/or the participants involved in the data collection. Suryani (2008) suggests that to counter biased views and also to help the researcher stay as neutral as possible, triangulation of the data should be made to ensure that the claims are supported from different perspectives. To reduce the biased views that will probably influence my work, I collected data with both the participants (students, pre-service teachers) and myself, that is, the teacher-researcher. Also, I compared and contrasted the participants' views from two different data collections: the first case study and the second case study. The purpose for comparing two data set is to strengthen the reliability and validity of the study. Another limitation mentioned by Suryani (2008) is that due to the nature of case studies, not many participants are involved in the data collection. This limitation of not capturing all ideas support Pothogsunan's (2010) claim that participants in an interpretivist research cannot give an explicit body of knowledge. This may result in the researcher not covering all issues. This limitation of not capturing all ideas can be responded to by using a multiple-case study approach. To cater for the limitation of using fewer participants or cases for this study, a multiple-case study approach will be used for the data collection.

Suryani (2008) suggested that when discussing the limitations of a case study, we need to have in our minds the rights of the subjects participating. This includes the confidentiality of the

participants and also allowing participants to refuse to answer certain questions. I will return to this in the paragraph on Ethics.

This study is a multiple case study because two cases were studied. The first case involved students in the first year of "Videregaende skole" (grade 11). This case study was named the KKG-case, after the name of the school (Kristiansand Katedralskole Gimle). The second case involved pre-service teachers including their mathematics education lecturer. This case study was named the UiA-case, after the institution where the teacher education was. In both cases, I was both the teacher organizing the math trail and the researcher, who collected data from the participants and from my own observations. When I speak of 'participants', I mean the grade-11 students in the KKG-case study, and the preservice teachers and the lecturer in the UiA-case study.

3.3 Design-based research (DBR)

Case study approaches are applied in all kinds of areas, such as medical research on one patient, or engineering research on one type of pump. They are not specifically tailored to educational research. Also, case study approaches do not specifically deal with the design of new learning arrangements such as math trails. Therefore, I turned to learn from a specific approach, namely Design-Based Research (DBR). DBR was chosen because it guides a research-based process to design tasks. These were needed for the math trail since I had to create tasks myself since tasks that suited my situation in Kristiansand are not readily available in textbooks or internet resources. To design the tasks, I planned to have a pilot study, and two consecutive case studies. For these three steps in the research (pilot study and two cases , the tasks that I designed for each step were evaluated and, if necessary, modified or replaced by other tasks for the next step. Also, I gained teaching experience with each step. This consecutive improvement of the tasks, and the gained ideas and experiences from a previous stage into the next stage are aspects of DBR.

The wider aims of DBR are however more theoretical than what I aim to achieve. For instance, Anderson and Shattuck (2012) define design-based research (DBR) as a research approach that seeks to increase the impact, transfer and translation of educational research into improved practice together with a need for theory building. In DBR, theory of design principles is used and developed, which guide, inform and improve both practice and research in educational contexts.

Bakker and Eerde (2015) also refer to DBR as an approach in research, with the potential of bridging the gap between theory and practice, because DBR aims at developing theories about domain-specific learning and the means that are designed to support learning. Bakker and Eerde (2015) added that DBR produces educational materials and knowledge of how these materials can be used. Akker et al. (2006) also define DBR based on their purposes. The first purpose is for development studies. In development studies, the purpose is to develop research-based solutions for complex problems in an educational setting. The second is for validation purpose, which aims to develop or validate a theory (p.16). Both purposes did not apply to my research, and I did not aim at theory development.

However, the following two characteristics of DBR mentioned by Bakker and Eerde (2015) suited my research; (1) it is research in which the design of educational materials is a crucial part of the research, and (2) the educational ideas for students or teacher learning are formulated in the design with the possibility for readjustments during empirical testing of these ideas. In my research, the educational materials were the math trails, and the readjustments were catered for by carrying the tasks and my experiences from one math trail case study into the next.

Anderson (2012) also defined some qualities that DBR should have. The qualities include that DBR should be situated in a real educational context, and should focus on the design and testing of a significant intervention. Using mixed methods, involving multiple iterations and involving a collaborative partnership between researchers and practitioners. In my research, this only partly applied. I organized the math trails with real students and preservice teachers (not with actors) and the intervention entailed that the math trails brought students and preservice teachers a new experience. However, for conducting the study, I was unable to engage in a collaboration with practitioners. I was happy that I could work with the students and preservice teachers, and that their teacher and lecturer let me be in charge of it all.

Akker et al. (2006) identify phases in DBR, which are: identifying the problem, analysis, design and development of a prototype, evaluation and the last phase is whether or not revision is needed after the evaluation. This was not relevant for my research, since I focused on the students' and pre-service teachers' experiences and perceptions regarding challenges and benefits, and not so much on what qualities of the math trails were reached in the different phases.

For designing tasks for math trails, teachers and researchers can find different advice. For example, Buchholtz (2017) offered a list of characteristics for tasks; these characteristics were already mentioned in the chapter with the Literature Review. Breen and O'shea (2019) also suggest that when designing tasks that would promote effective thinking in mathematics, tasks should engage students' particular practices of mathematicians. The tasks should let the students feel that they are thinking and looking out for solutions as a real mathematician will do but not just follow a procedural way of solving tasks. Additionally, Kusmaryono (2014) mentions that for students to have a real feel of what mathematics is about, situations in which students will be active, creative and responsive to their environment should be created.

Shoaf et al. (2004) suggested characteristics of math trails tasks. First, math trails are for everyone, thus they should be interesting and accessible to people at all levels of age experience. The aim is for everyone to feel the accomplishment of contributing to problem-solving and not just math lovers or A-students. Second, math trails are cooperative, not competitive. This means math trails are not interested in the individual getting the right answer but rather the processes for formulating and solving problems. Third, a math trail should be self-directed, so far as the participant is ready to trail the path; in my case, the GPS-based math trail and the app would assist in giving directions. Fourth, math trails are voluntary and not to be done out of compulsion; in my case the math trail was obligatory for the students in the KKG-case study, but voluntary for the pre-service teachers in the UiA-case study. Fifth, a trail should be opportunistic, it can occur everywhere whether, in the shopping mall, park, zoo etc. math trails are temporary because places change. Sixth, the tasks in a math trail should be fun to carry out and by doing that, the designer should consider the location, length, trail guide, and the mathematics involved..

3.4 Research method

Alharahsheh and Pius (2020) describe research methods as modes of data collection and analysis techniques that together produce and develop knowledge. Bryman (2016) also defines research methods as the techniques for collection of data. A research method can involve specific instruments such as questionnaires, interview guides, or a structured sheet to guide observations.

In my study, I employed qualitative methods for the data collection. Qualitative methods are appropriate in interpretivist studies. This is because the researcher interprets meanings from the

qualitative data collected (Alharahsheh & Pius, 2020). Ercan and Marsh (2016) mention that the aim of adopting qualitative methods is to develop an understanding and an interpretation of the way in which the participants of a study understand their actions and the context in which they act.

Bryman (2016) suggested that for a qualitative research, attention has to be paid to factors such as reliability, replication and validity.

3.5.1 Methods for data collection

The data collection was based on two GPS-based math trails, one at a secondary school (to be explained below) and one in primary teacher education (to be explained below). Before these main data collections, I conducted a pilot study with some friends. After this pilot study, necessary adaptations in the tasks and the questionnaires followed. The main instruments used in the data collection were the tasks in the math trail designed by the researcher and an interview guide. The purpose of this piloting was for me as a teacher and researcher to gain experience with the nature of the tasks, their validity, and whether the participants would use the mathematical knowledge as purposed in the tasks or whether it would turn out differently. The pilot also served to find out if the locations chosen for the math trails activity were in line with Shoaf et al. (2004) and Buchholtz (2017) math trails qualities.

As said before, my main data collections came from two cases. The first data collection was carried out with students from Kristiansand Katedralskole Gimple (the KKG-case study), and the second data collection was carried out with students from the mathematics department at the University of Agder (the UiA-case study).

The data were collected using two instruments, which were (1) tasks (math trails activities) (2) an interview guide. Additionally, I personally wrote my (3) researcher's observations. Thus, the data resources on students' and teacher's perceptions came from the grade 11-students, the preservice teachers, the UiA-lecturer from the interviews and my observations during the design, the organization and the implementation of the math trails. In both case studies, the math trails activity was followed by an interview.

The math trail activity were carried out in groups. I asked that each group to have at least one representative to speak for the group, whom would be interviewed by me, the researcher. With one representative from each group, I would receive information from each of the groups and receive a description of what went on in their group and how each group had experienced the activity.

In my math trails, the tasks were used so participants (students and preservice teachers) would have the math trail experience. The tasks were not used for assessing the students. Their teachers were not informed by me about their answers, but I looked at the answers to gain insights into the benefit and challenges of GPS-based math trails. Not being assessed as meant that the participants would not need to worry about whether they performed the tasks right or wrong.

Methodological framework

Table X shows the methodological framework for how the research questions would be answered. I repeat the four research questions, of which the first two is set from the participants' perspective, and the final two are from the teachers' perspective:

1. What are challenges students face when participating in a GPS-based math trail?
2. How do GPS-based math trails activities benefit students?
3. What are possible challenges teachers face when planning and implementing GPS-based math trails activities?
4. What are benefits teachers derive when planning and implementing GPS-based math trails activities?

Table X: Methodological framework of the study

	perspective	data sources	
		KKG-case study	UiA-case study
Research questions 1 and 2	students' perspective	interviews with students	interviews with pre-service teachers
Research questions 3 and 4	teacher's perspective	my observations	interviews with pre-service teachers and UiA-lecturer my observations

Table X gives an overview of the participants, including myself, in the two case studies, and how these participants contributed to answering the research questions. In the first caste study, the participants were the KKG-students (grade 11), and their answers contributed to answering the research questions regarding the students' perspective, namely research questions 1 and 2. In this case study, the KKG-teacher could not be interviewed and hence, only my observations were a resource for insights from a teacher's perspective.

In the second case study, the participants were pre-service teachers at UiA, their UiA-lecturer, and me. Since the pre-service teachers were already in their 4th year, they could play a double role, namely as both students (learners) and as teachers (potential organizers of math trails). So, they were able to answer questions both from a student perspective and from a teacher perspective. Hence, their answers contributed to answering both the research questions regarding the students' and the teachers' perspective, that is numbers 1, 2, 3, and 4. In this UiA-case study, I was also able to interview their lecturer. His answers, plus my own observations also contributed to answering the research questions regarding the teacher's perspective, that is, the research questions 3 and 4.

As can be seen, my own observations were supplemented by other data, namely from the pre-service teachers and the UiA-teacher. However, it should be noted that the preservice teachers and the UiA-lecturer had no experience in designing or organizing a math trail, hence their perspectives was based on less responsibility for the successful implementation of the math trail than mine. However, their input and evaluation on what should have been included to make the math trails activity a better learning tool for students and teachers was most valuable.

3.5.2 Participants

As mentioned earlier, two groups participated in the data collection. The first group consisted of 11th grade students from Kristiansand Katedral Gimle (KKG) Skole. The second group of students were the 4th year pre-service teachers from the mathematics department in UiA. The pre-service teachers' group included a lecturer who was teaching the group during the period of data collection. The pre-service teachers' were chosen because I wanted to know their thoughts as future teachers of mathematics and also, as students who study mathematics (double role participation). More descriptions about the participants of each group are provided in chapters 4, 5 and 6.

The participants for the first case study are students who have some mathematical background. However, the participants of the second case were pre-service teachers in mathematics education who interested in learning and teaching mathematics. The participants of the first case have mathematical background, who may either major in mathematics or major in a different subject depending on their interests. The purpose for selecting these groups of participants is that, they are all students who are learning mathematics. Therefore, they can share their experiences in mobile math trails regarding its benefits and challenges for students. On the other hand, the pre-service teacher together with the lecturer involved, played double roles. This includes how they think the activity would benefit students, pupils and teachers. As in the things they would eliminate from the math trails activity in order to make sure that students and pupils don't encounter challenges. In addition, they share their experience as students who participated in a math trail. More details about the participants are provided in the chapters 5 and 6.

3.5.5 Interview

For the collection of the actual data, interviews were conducted. A semi-structured type of interview was conducted. A semi-structured interview is a type of interview in which the interview consists of several key questions that help to define the area explored as well as allow the interviewer to ask further questions to get a better response or more details of what the interviewee says. Asking of follow up questions was conducted to strengthen the validity of the participants' response. Especially in the case where the interviewer is not sure about the response of the participants, or wants to know in-depth, what the participants means by the response given. Conducting interviews is a key tool in interpretive research. This is because, interviews allow participants to express themselves about how they feel regarding situations (Phothongsunan, 2010). The purpose of the interview is to provide a deeper understanding of social phenomena that

would not have been obtained from a purely quantitative method. In other words, the purpose of the interview was based on the constructionist position that social actors influence culture and organizations (Bryman, 2016). In this study, the interview follows a structure; however, based on my observations and for clarity of answers, other questions which are not part of the interview guide will be asked. This makes the type of interview employed for data this study, a semi-structured interview.

Qualitative data are often collected through interviews. This is because, it allows the interviewees to speak in their own voice and express their own thoughts and feelings. Interview also allow researchers to investigate people's views in greater depth (Alshenqeeti, 2014)

Opdenakker (2006) suggested ways of conducting interviews which include; face-to-face interviews, interviewing by mobile phone, and interviewing using the internet. de la Croix et al. (2014) also suggested ways of conducting interviews which include; one-to-one interviews, group interviews and stimulated recall interviews. In a stimulated recall interview, the researcher observes the behavior of the participants and asks questions about how the participants behave in that way. Details on the type of observations employed for the study are mentioned in chapters 5 and 6.

As suggested by Doody and Noonan (2014), the researcher, should first explain the type of interview to be conducted, its nature, and the general format the interview should take. In addition, the researcher should inform the participants that, there are no right or wrong answers. But rather, the participants are encouraged to share their experiences in a sincere manner. This helps to strengthen the reliability of the data given.

Interview has many advantages as mentioned previously by Opdenakker (2006), de la Croix (2014), Alshenqeeti (2014). however, interviews as a method of data collection has its disadvantages associated with it. Some of the disadvantages in conducting interviews are that they consume a lot of time, it involves small scale study, potential for subconscious bias and potential inconsistencies. Doody and Noonan (2014) stated that, interviews are susceptible to bias. The bias include: The participants desire to please the researcher, participants saying what they think or feel the researcher wishes to hear, the researchers view can influence the participants responses by expressing surprise or disapproval.

The interview conducted will be audiotaped and transcribed after which the audio recording will be destroyed.

3.5.5.1 Interview guide

For a quality interview, the researcher or interviewer needs to know in advance the study phenomena of where detailed insights are required of the participants (Gill et al 2008). In order to obtain a quality interview guide, literature were reviewed and piloting of the instrument was conducted to get an idea about the possible challenges and benefits students faced when participating in a math trail.

The interview questions will consist of three parts, the first part looks at the challenges, the second will be about the benefits they derived and the third part about any other concerns they would like to talk about but were not mentioned during the interview. The interview guide will be moderated after each data collection in order to improve upon the final data collection.

For this study, the researcher will take the role of interviewer and the participants of the math trail will assume the roles of the interviewees. For further clarification of the answers given by respondents of the interview, questions will be asked.

3.5.6 Observations

Observations can be conducted on nearly any subject matter. However, the kind of observations will depend on your research questions. In the observation of people, two common types of observations can be chosen; (1) participant observation and (2) unobtrusive observation. In participant observation, the researcher may interact with the participants and become part of their community. In obtrusive observation, you do not interact with the participant, but rather simply record their behavior (Driscoll, 2011).

As part of the data collection for this study, the researcher observed the participants of both cases using the two observational methods described by Driscoll (2011). The observation for the first case was participant observation, while unobtrusive observation was employed for the second case study (Simpson & Tuson,2003).

Observation method of data collection was chosen because; observations can be used to address a variety of research questions, it can be applied in a variety of contexts, it can demand a variety of research skills, observations can give direct access to social interactions, etc.

Bell and Waters (2018) critiques the participants' observation method in view that, the accounts of observations can be subjective, biased, impressionistic, idiosyncratic and lacking in the precise quantifiable measures that are the hallmark of survey research and experimentation.

3.5.7 Data analysis

The thematic analysis of data was employed for the data analysis of this study. Kiger and Varpio (2020) describes thematic analysis as method for analyzing qualitative data by searching across the data to identify, analyze and report repeated patterns. Kiger and Varpio (2020) outline the steps involved in thematic analysis which includes; familiarizing yourself with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report /manuscript. These steps were adopted for the analysis of this data.

To familiarize myself with the data, I read and re-read the transcripts for three to four times. After reading several times, I became familiarized with the data. Through the familiarization process, I noticed key ideas which was common, throughout the data. Codes were generated for these common ideas. By generating codes, I colored my texts based on the codes assigned to them. Some texts had more than one code. The codes were generated were geared toward answering the four research questions of this study. After the codes generated, they were grouped into groups. This is where the themes are formed and this is the third stage. After grouping the codes into the various themes, you have to review the themes. This is done by verifying if a code fits under a specific theme. From the transcripts, it was realized that, a participant's response to a particular question fell under more than one theme.

After that, the themes were named and defined. And in the final step, manuscripts from the transcripts were provided to support the themes in the results. To broaden the analysis, discussion id done by relating the themes to research question. This is done by discussing the implication of findings; and questioning the assumptions or pre-conditions that gave rise to the themes. In addition, adding of references is done to strengthen the analysis by building support for which particular themes were selected (Kiger and Varpio,2020).

Some of the advantages thematic analysis are; it is simple to learn and apply, it is a powerful method for interpreting a wide range of data set since it allows researchers to summarize and highlight key ideas.

Thematic analysis is critiqued for the fact that, thematic analysis doesn't really have a particular method, but as simply referring to a process for identifying patterns (Terry et al, 2017).

3.5.8 Pilot study

Hassan et al. (2006) define a pilot study as mini-research which is done prior to the main data collection to test protocols, data collection instruments, sample recruitment strategies and research techniques. It helps in knowing the feasibility of a study protocol. Connelly (2008) admonishes that it will be good for a researcher to use a population that is different from those recruited for the main study. Conelly (2008) suggested based on other researchers' experience that ten per cent of the chosen population is okay for a pilot study. Conelly (2018) further adds that a pilot study may be carried out at one site to test procedure and then be will be used in a multi-site study. According to Morin (2013), one of the purposes of carrying out a pilot study is to find out possible factors that will discredit the reliability and validity of the research to be conducted as well as lookout for ways to eliminate these factors as much as the researcher can. She further suggests some issues that should be looked at are; background, the feasibility of the objectives, informed consent, and interpreting of results within the context of feasibility. For the feasibility of my research methods, a pilot study was conducted to test the instruments that will be used for the main data collection.

Initially, the math trail activity was planned to be carried out at the fountain near the Kristiansand Domkirke and the playground at Bystranda; however, the task locations together with the tasks were changed after the piloting. The main reasons for the massive change were;

1. The distance between the tasks locations was quite big. It took about 15 minutes to move from one point to the other. Also, there were no suitable tasks locations in between the distances to engage the participants.
2. The tasks were changed as a result of the tasks not fitting the new task locations. However, some of the mathematical contents like estimations and calculating the slope were included in the learning outcomes of the new tasks designed.
3. From observations conducted by me (the researcher), it was noted that, the participants of the pilot study experienced difficulty understanding the task's description at the Bystranda playground. This drew my attention to make the task's description in very simple and clear language. The researcher had to explain.

4. Interview questions regarding how the math trail activity benefitted teachers were not asked. However, it was later included in the interview guide of the pre-service teacher's math trail. This is a weakness on the part of the interview guide used for the study.

3.5.9 Ethical consideration

The data was carried out while considering ethical issues. Permission for the KKG students to participate in the study was sought. In addition, the teacher also made known to the teacher's head of department at KKG; regarding the participation of the students. Also, permission for the pre-service teachers to participate in the study was sought directly from a lecturer who taught the participants.

For ethical considerations, participants will be selected based on voluntary participation. The math trail activity was described to the participants. After the introduction, the participants were given information letter and consent form (Appendix 2) to read and sign. The purpose of the letter was to reaffirm the decision that, participation in the research is voluntary and they were free to withdraw anytime the participants wished to.

The participants' confidentiality and anonymity was highly considered as suggested by Driscoll (2014). The data transcribed did not include the names of the participants but rather, letters and numbers were used to represent the various participants. In addition, the data was transcribed in such a way that, participants' identity will be hard to trace. References from all the literature used in this study are provided throughout the text.

3.5.10 Biasness of the study

The study was biased as mentioned earlier. This is because, I personally wrote the observations included in the data. Also, the collection of data was based on the participants and researchers' subjective opinions and feelings about the math trail activity.

Also, the researcher played multiple roles; as a researcher, an observer and a teacher. This makes the data gathered from the researcher biased.

3.5.11 Validity and trustworthiness

The findings of the research study were not solely based on the researcher's point of view. The instruments employed for the data collection were scrutinized by my supervisor. Some of the questions were asked by my supervisor to strengthen the validity of the data and results obtained.

Also, to increase the reliability and validity of the study, observations was carried out in order to become informed, the kind of follow up questions to be asked by the researcher. Moreover, the participants were entreated to give their honest views about the math trails activity. The participants were made aware of that, the researcher designed the math trail activity; therefore, the participants were encouraged to give honest feedback and not to be intimidated by the researcher. This provides the assurance that, the data is reliable and from honest sources.

Also, multiple cases were conducted, compared and contrasted to strengthen the reliability of the study.

In conclusion, the study of this results meant for making suggestions.

CHAPTER 4

Report of the first case study, the KKG Math trail

4.0 Introduction

This chapter describes the case study of the math trail activity which was carried out with the grade 11 students at the Kristiansand Katedralskole Gimle (KKG). This was the first math trail activity, in which I used the GPS-based app, Actionbound. This chapter includes a section about the methods used for this specific case study, details on the math trail activity, and tasks, interview guide used for the data collection and how the thematic analysis carried out for analysis. Yet, the main part of this chapter holds the results based on the interviews held and on my observations during the activity. The last section holds the conclusion of this case study, which were used in the second case study described in the next chapter.

4.1 The math trail activity

The actual activity started in the morning around 8:00. That was the time for the math lesson and it was a 1 hour and 20 minutes' period. After the students had received measuring tapes, they scanned the codes to get access to the math trail in the Actionbound app on their phones. The various groups chose themselves which particular location they wanted to begin with. Some groups started with the white building, while another group started with the bicycle playground and the rest of the groups started at the bicycle parking. Most of the groups ended their trails at the Oddernes Cemetery. Before the groups left the classroom, they were provided with a measuring stick and noteboo for writing. The participants were to provide their own mobile phones, calculators and were allowed to access the internet when needed and if they wanted. All the groups used the calculators on their phones for calculations.

4.2 Tasks

As mentioned by Bakker and Eerde (2013), design of educational materials is a crucial part of this study. Tasks were part of the educational materials for this study. The tasks were designed by the researcher and were inspired by an earlier Math Trail at UiA with the same GPS-based app

designed by Nils Buccholtz and Pauline Vos (not published, but the tasks were made available to me). The bicycle playground tasks ideas were inspired through the Nils Buccholtz and Pauline Vos math trails tasks. The wheelchair ramp tasks were modified based on the example from Buccholtz and Vos tasks. However, the tasks locations were different from the locations in Buccholtz and Vos tasks. The tasks in the KKG Math Trail were based on the following mathematics content areas; area, percentages, and making estimations such as how long will it take for a cemetery to be full, how many people can occupy a space, how many more bicycle parking lots will be needed etc. tasks are listed in Appendix 4a. Before the math trail at KKG, I had piloted this particular Math Walk with a friend to see whether the technology worked well. All the tasks were designed in such a way that students would see the connections between the classroom mathematics and the environment.

In preparing for the activity, I had used the Actionbound software to include pictures with the tasks to make identification of the locations easy. Also, to guide the students in answering in the app, I had included the form of objectives or range form in which the answers could be written. When students would insert an answer into the app that matched the predefined answer, they would receive points.

The tasks were located at the Oddernes Cemetary and KKG. These two locations are not far from each other and it takes about two to three minutes to walk to and from both ends. The table below presents the locations, tasks and their learning outcomes. As stated earlier, connection between classroom mathematics and the environment was a desired outcome for all.

LOCATION	TASKS	DESIRED OUTCOME
The bicycle parking lot	There are 1600 students and 200 teachers at the KKG. If 80% of this population decides to come to school by bicycle, how many of these bicycle parking lots will be needed?	Participants are able to apply their knowledge in percentages. The participants are make estimations and also have a knowledge about the sufficiency of the parking lot.

	Do you see the rectangular field from entrance 3.1 to 3.4? How big is this portion in meter square?	Participants are able to make estimations, by calculating the area. This will help the participants to have a view of the number of people that that can fit into the area while observing 1 meter distance.
Finding locations	All tasks regarding finding location	Participants are able to navigate with the help of GPS.
The white building	a. building regulation demands that the slope of a wheelchair is not steeper than 1:12. Is the wheelchair ramp the white building designed to suit this regulation? b. What is the slope of the ramp in percentage?	Participants are able to apply trigonometric ratios. Participants become aware of the safety of the slope of the wheelchair ramp.
	do you see trees in front of the building of approximately the same height? Estimate the height of this tree.	Participants are able to make estimations
The bicycle playground	Do you see the curves which the bicycle passes on? this is a part of a circle. How big is this circle in the meter square?	Participants are able to think beyond what they can see. Participants are able to calculate the area of the circle.
The Oddernes cemetery	This is the Oddernes cemetery closer to the UIA bus stop. How	Participants are able to estimate the number of graves and also

	wide is the space from the line on the last burial to where the yellow signboard? a. How many graves can fit into this yard? b. From 2017 to 2019, 387 graves have been buried in the new Oddernes cemetery. how many years will it take for this yard to full?	forecast the number of graves that can be dug at the calculated area.

Table g: math trail tasks and their desired learning outcome

The tasks designed in the table g, were put in the Actionbound app. The math trail included the following locations; the bicycle parking, the white building, Oddernes cemetery and the bicycle playground. Before the students began the math trail in the app, a welcome note was given to them and then the things (phone with internet connection, measuring tape, notepad and pen) which were needed to make their math trails activity easier were listed as a form of remembrance after which the tasks followed.

4.3 Interview guide and interviews

An interview guide was developed based on my experiences with the pilot and aimed at identifying challenges and benefits of the math trail. The interview guide contained 19 questions and these questions asked were also influenced by my observations. The questions asked were a mixture of close and opened ended questions since some questions demanded some yes or no answers. However, further questions were asked as to why the students chose that particular answer they gave.

The questions in the interview were not directly corresponding to the tasks that were given to the students but rather they were interviewed with regard to how the whole activity went. Emphases

were not put particularly on how the students solved the tasks although they were provided with notepads to take notes or put down things which were necessary to them. However, much emphasis was put on how the whole activity went; the nature of the tasks given, locating the places, the challenges they faced and the benefits they derived from the activity in general. Nineteen questions were written down in the interview guide, however, based on some of the responses the students gave and what had been written in their notes pads further questions were asked. The students were asked to open up and express their views and opinions about the activity. For the interview guide for the KKG case, see appendix 4b.

The interviews were conducted face-to-face. As mentioned earlier on, each group had at least one representative for the interviews. The participants were encouraged to speak freely without fear. This is to strengthen the reliability of the data. In addition, the participants were encouraged to ask for explanation if they were not clear. I also clarified the interview questions, if a participants' facial expressions showed signs of confusion. This was done to strengthen the validity of the responses to the interview questions.

The interview was transcribed in such a way that the anonymity of the respondents was taken care of. There were seven respondents in all and the first respondent is named R1, the second R2 and it goes on up to R7. The I in the transcription represents the interviewer. It was a semi-structured interview and the interviewees were asked different questions depending on certain kinds of answers they gave

4.4 Participants

The participants in the case study were students from (Videregående) at Kristiansand Katedral Gimle. The students were from the first-year under the International Baccalaureate (IB), which corresponds to grade 11. Students had already studied most of the mathematical topics which were to be used for the activity except for trigonometry ratios which they were yet to study. They were about 20 students in the class of which 15 of them volunteered to participate in the activity. Out of these 15 who volunteered, 7 of them also agreed to participate in the interviews. As a result of that, groups were formed such that, I had at least one of the people volunteering to participate in the interview in every group. The majority of the students were 17 years and above so they gave their consent except for one student who was sixteen years and hence needed consent from parents. But before volunteering, students had been already briefed about what the math trail is, how the activity

was going to be done and the app that needed to be downloaded. Students had never participated in such an activity before and had also never used the app 'Actionbound' for finding locations and working. Pseudonyms are provided for those who partook in the interviews and were named according to the number of the group.

4.5 Results and findings

To answer the research question what are the benefits and challenges of doing math trails, an interview was carried out whereby some of the participants were interviewed to share their experiences about what they liked and disliked about the activity. These challenges and benefits are looked at from two dimensions; that of the researcher and task developer and that of the participants. Transcripts of the interviews can be found in appendix 4c.

The thematic analysis for qualitative data was employed for the analysis. Kiger and Varpio (2020)'s steps of thematic analysis were adopted. The table e below shows the codes and their meaning.

FINDINGS	CODES
Finding the location	FTL
Getting points for finding the location	GTPFL
Understanding the tasks	UTT
Scanty information in task description	SITD
Identifying the math concepts	IMC
understanding the mathematical idea	UMI
Weather	W
Time factor	TF
Provision of relevant materials	PRM
Taking measurements from other groups	TMFO

Frequency of having math trail	FRG
Doing actual measurements take time	AMTT
Reality of mathematics	RM
Fun	FUN
Some mathematics not applicable to the outside world	SMNA
Connection with the society	CWS
Math trails meet some types of learning needs	MLN
Time factor	TF
Physical activity	PA
Challenges and difficulties	CHAL
Benefits and other positive results	BENE
Outdoor learning	OUTD
Attitude	ATT

Table h: meaning of the codes generated

The table 15 below presents the codes and the themes they fall under.

THEME	CODES	G1	G2	G3	G4	G5	G6	G7
LOC	FTL	FTL	FTL	FTL	FTL	FTL	FT	
	PFTL	PFTL	PFTL					
	UTT	UTT	UTT	UTT	UTT	UTT		UTT
	UMI	UMI		UMI	UMI	UMI	UMI	
	SITD							SITD

	IMC	IMC	IMC	IMC		IMC		IMC
	GUE			GUE				GUE
	PRM	PRM	PRM	PRM	PRM	PRM	PRM	PRM
	TF		TF	TF	TF			
	AMTT			AMTT	AMTT			
	TMFO	TMFO						
	PoA	PoA						
OUTD	RM	RM	RM	RM	RM	RM	RM	RM
	FRQ	FRQ			FRQ			
	SMNA	SMNA						
	W	BW	W	W	W	W	W	
	FUN	FUN	FUN	FUN	FUN		FUN	
	MLN	MLN			MLN		MLN	MLN
	TW	TW	TW	TW				
	UMC	UMC	UMC		UMC	UMC	UMC	
ATT	FUN	FUN	FUN	FUN			FUN	
	IMC	IMC	IMC	IMC		IMC		IMC
	AMTT			AMTT	AMTT			
	UMI	UMI		UMI	UMI	UMI	UMI	
	PFTL	PFTL	PFTL					

Table i: the codes and the themes they fall under.

The table I presents the codes and the themes they fall under. The G1-G7 represents the groups that participated in the interviews. From the table, it can be observed that some cells are empty. This is as a result of a group not mentioning that difficulty or benefit. For example, G4,G5,G6, and G7 did not mention anything regarding teamwork (TW). However, G1, G2 and G3 mentioned how, the math trail promoted TW among their groups.

4.5.1 Observation from the researcher

Participant observation method was employed for this case study. The participant observation was employed because the researcher asked the participants questions: and also made explanations to participants, if the participants faced difficulty understanding a task. As the students began the activity, I observed the group at the white building. They asked about the angle which I explained to them and asked the way of finding it but I told them to search online. I saw them doing some measurements for the measurement of the slope. They had the measurements right.

Observation was done on other groups who were at the entrance 3.1. Two groups were observed joining forces by combining their meter stick to make the measurements go faster. Most of the groups decided to go to the cemetery but one group went after the other. The last group to leave the bicycle parking lost their way while searching for entrance 3.4. I drew their attention to the description which stated “towards UiA”. There was one person who was discussing something unrelated to academics and decided to stay out of the activity, however, his partner joined another group to participate in the activity. The participants used their steps to also estimate the length instead of the meter rule. A similar thing was done at the cemetery tasks too.

At the cemetery, the students discussed a lot among themselves, they were confused a little about the second tree but I helped them to identify the tree. They measured the length as they were supposed to, measured the distances between the graves and did a lot of brainstorming about how to go about the tasks. They thought about whether the graves dug were the same or not because it depended on the size of land you buy for the burial. However, the activity was disturbed due to heavy rain which made us end the math trail forcibly.

I was unable to observe the students at the bicycle playground. However, I met one group returning from the bicycle playground. This was after every one was in class except this group.

4.5.2 Challenges and benefits from the participant's point of view

Excerpts were drawn from the interview conducted with the participants. These excerpts are focusing on participants' views about the activity with regard to its benefits and challenges.

4.5.2.1 Challenges

Location and technical challenges

One of the major challenges in the math trail was students finding the locations but couldn't get the points because they didn't fall into the area demarcated for the points. Generally, finding access to the place wasn't very difficult. However, the map in the Actionbound said they were not there although they were there. This is because the app was designed in such a way that the participants would get some points for finding the location. But the participants needed to be in a specific location ring or very close to a specific location before they could get the points for finding the location of the place. The participants couldn't get the points when they found the location because, they were a little far from the area demarcated for getting the points.

The respondent for the first group mentioned it was not difficult finding the location because they got to do the tasks, the picture in the app helped them locate the right place. However, the GPS told them they were some meters apart from their destination. They were directed to the place by the map but the exact place to locate where to get the point was the problem. But once it takes them to the area where a task is to be carried out, they would find the tasks there. Although finding the location is a key factor for the math trail, participants not getting any points for finding the location was disappointing to the participant. The participants were not able to get the points for finding the location, however, they were able to get to the location and carry out the tasks. This was the main purpose of the GPS. To be able to get the participants to the tasks locations and carry out the tasks. However, not getting the points swayed the participants' attention a little from their goals, which made it challenging.

This was also the case for R2 as well. But in the case of R6, the challenge of finding the place was a challenge because of a pre-image they had about the place. Pre-image in the sense that, they were expecting to find a wheel-chair which they did not. Therefore, although the GPS took them to the

right location, R2's group thought they were at the wrong location due to their misconception. However, they found the place, probably due to the picture provided in the Actionbound app.

Excerpt 4.5.2.1.1

I: was it difficult finding access to the place?

R1: I didn't find it that difficult to find the areas. Although Actionbound had a tracker on the phone, I wasn't kind of able to locate the place although we were at the right place. but we got to do the tasks anyway.

I: was it difficult trying to find the locations you were supposed to go to? Did you get any points for getting to the points?

R2: no. we still got a hundred points for getting the right answer but not for the locations.

I: was it difficult finding access to the place

R6: it was a bit difficult, with the first exercise, we went to the point that the map showed us but we didn't really find a wheelchair but we found the place afterwards.

We were beaten by time as students had about one hour thirty minutes to complete the activity. Most of the groups went to only two locations whereas others went to all the four locations however, the participants couldn't finish because they had another class scheduled right after their math lesson period. This made it more challenging as it has begun to rain heavily.

Time

Excerpt 4.5.2.1.2

I: so do you think if you had enough time you would have completed the tasks?

R1: yeah. I think we had one area left to go to if not for time's sake and the rains.

I: probably because it rained and you couldn't complete the task but do you think if you had more time, you would have been able to complete the tasks?

R2: oh definitely. But we had to come back early because it started raining very bad and the books were getting wet and the phones were getting a little wet but I think if the weather wasn't that bad we could have completed all the exercises.

I: did you see the weather as a challenge?

R1: it was cold, but it didn't hinder our ability to do the calculation but since we had to travel around that was a bit difficult. I would probably be able to do the tasks even if it rained. But if the rains are heavy and snowing heavily with windy weather then it will be very challenging

I: so if you had enough time, would have liked to complete the tasks?

R3: yeah. We just had one task left so it would have been fun completing that one but because it was raining it was not possible.

I: so what can you say about the activity that is the math trail in general?

R5: I would say the weather was the most horrible factor, I felt like the measuring tasks and the counting tasks were just useless. Because we all know how to measure and count, its just basic math. But for other tasks like the circumference of the circle, and the slope, we had to think and that was when we were doing the real math and was useful. Because you have to think about how am I going to do this thing and not just some straight forward, tasks.

Another challenge that the participants faced was that the information in some of the tasks were few so they were confused at some points about what they were actually supposed to do. Especially the groups which did the tasks at the bicycle ramp. The respondent R7 said that the tasks lacked detail and did not know what to do.

Excerpt 4.5.2.1.3

I: Was it difficult getting the mathematical ideas behind the tasks?

R7: we didn't understand what the description meant, an example is the tasks at the bicycle ramp.

I: was the materials provided sufficient for you?

R7: yes. In some cases, it was a little bit too short. There was a question to check the length of something but they didn't say exactly what?

Another challenge the students faced was understanding the tasks. The difficulty had to do with some kind of word they found in the tasks which were new to them and therefore could not understand the task.

Looking at the difficulty of trying to understand the tasks, it had more to do with which of the tasks each group were able to complete. Also, if a group was to understand the words used in the formulation of the question, then it was easier for them to understand the tasks. The groups which completed the tasks at only the bicycle parking lot and the cemetery had their responses quite different from the groups which went to the white building and the bicycle playground. From the respondent for the first group, she mentioned that some of the words were hard and they weren't familiar with those kinds of words which made the understanding of the tasks difficult. Also, she mentioned that some expression like rounding up the answer was not something they understood very well which made them lose some points. However, the respondent for the second group said that it was not difficult to understand the tasks but they only ended up spending more time on the tasks because they acted on impulse. This group did the tasks at the bicycle parking lot and the Oddernes cemetery but not the white building task and the bicycle playground task. The respondent for the third group also said that apart from the bicycle playground tasks all other tasks were not difficult to understand. They had difficulty understanding the task because they couldn't find the circle whose radius was to be calculated. For the fourth group just like the second group, they didn't understand the task, not because of the wording of the tasks but because they didn't read the question properly. The fifth group also said it wasn't difficult to understand the tasks.

Excerpt 4.5.2.1.4

I: was it difficult trying to understand the tasks?

R1: some of the tasks had words that we weren't familiar with.

I: What kind of words?

R1: I don't remember the exact words but I think it was the tasks at the white building, like the angle of elevation, we have never heard of it before. That was hard but other than that I guess, we saw another task which we couldn't really understand but the question was to round up the answer we didn't know so we lost some points there.

I: was it difficult to understand the tasks?

R2: no. it's just that, our team kind of acted on impulse, "okay let's do this" but we should have just stopped for a minute and actually read the question properly before proceeding. We ended up spending a lot of time on one question because we didn't read it properly the first time.

Provision of materials

Also, the participants had a challenge with the tools that were provided as they complained that it was too short and would have another type of tape measure where they just pulled out and push in. For students to work outside the classroom, they needed some instruments of which some were provided by the researcher. The researcher provided the students with a two-meter foldable measuring stick and the students were to measure a thirty by sixty area rectangular field and a thirty by 18 rectangular field. Each group was provided with two measuring sticks however, most of the groups complained that the measuring stick was too short and as a result of that, other groups devised ways of measuring the area by using a mobile app, while another group measured the distance between their steps and used that to measure the distances. Other groups also came together and combined their measuring sticks which means using four sticks instead of two at a time. In the interview, some respondents said that they would have preferred the measuring tape which you pull and then press something for it to get back in. Another also said the materials provided were the best that could have ever been provided for the activity. However, the students managed to use the materials provided as much as they can to solve the tasks. The respondent for group one preferred if some formulas were written down for them to use but also doubted if that was actually the best or if it would have been regarded as cheating. Group five didn't have a problem with the instruments provided just that it took them a lot of time.

Excerpt 4.5.2.1.5

I: did you need other materials that were not provided?

R4: Yeah, we wanted the other type of measuring tape. That would have made the measurements simpler. Although the measuring stick helped us in measuring, it also took a little bit longer.

R5: measuring stick was really short, so we measured without the stick but we got it right eventually. We could have used the stick but it was going to take time and it was raining as well. We didn't use the writing pad but rather the calculator and the stick.

R1: yeah, it was useful, but the measuring stick was short.

I: and did that give you any problem?

R1: I'm not sure, to be honest. So we just measured our steps with the stick and measured the dimensions with our steps.

While others complained about the shortness of the stick, R2 was rather appreciative of the shortness of the measuring stick because it promoted teamwork. R2 was more appreciative of the measuring since it connected to the tasks. Therefore, unlike the other groups complaining about the shortness of the measuring stick; the measuring stick promoted teamwork for R2.

Excerpt 4.5.2.1.6

I: was the materials provided enough?

R2: yeah. Honestly, the best that could have been provided to us because, it was really connected to the tasks and also connected with teamwork, and I think the number of people in the group was good and having two measuring sticks made it easier for us to carry out easier instead of using one, it made our work more effective and efficient. And being able to notice some things down on a notepad was great because if we want to remember something then we can quickly go back to it.

4.5.2.2 Benefits

To find the benefits that students derived from the math trail, they were asked to share their feelings about the activity and how it can influence their learning of mathematics.

Reality of Mathematics

One of the major benefits that students derived from this activity was that it took them from the classroom where they always had math lessons to the outside world of the math classroom. This helped take the boredom of learning mathematics in the classroom. By learning outside the classroom, students get to learn in a different situation. That is the students learn in a real situation where the feeling of learning in such situation is different from the classroom situation. The students learn in a situation where they get to think about what actual thoughts that go into the making of wheelchair ramp. By learning outside of the classroom in real situation, it provided opportunity for the students to know how the book measurements look like in actual measurements.

R3 mentioned that doing math trails activities will motivate students to learn mathematics well. This is because, they get to use the mathematical formulas learnt in real life.

Excerpt 4.5.2.2.1

I: so what can you say about math trail in general?

R2: it's a great way to learn math, it's a great way to understand math, it brings a lot of meaning to math and personally I felt like most of the students liked it but of course, I can't tell for everyone. But generally, we all had fun doing math outside of the classroom. So if this is worked upon to be included in the curriculum it will really benefit the students.

I: don't you think it's because you don't go out to do tasks that is why you think mathematics is abstract?

R3: yeah. Because I will be more motivated to learn because I know how to use it in real life instead of just using it in a book and don't see the point of doing those tasks.

I: If mathematics or mathematical tasks are to be carried out of the classroom,(like you learn about the area and you are given a task to find the area of a field where the measurement is done by you) will it help you understand mathematics better and also better appreciate the value of mathematics?

R4: Yeah, because then we get to see how we can use the mathematics in different situations and not just an example in a textbook.

I: do you think that such activities should be included in your curriculum?

R6: Yeah, I think so. Because sitting in class is just getting boring, so for a while, it's just important for students to just go outside and work with mathematics and this will make mathematics really interesting and always sitting in the classroom. And it is very beneficial for students.

It also helps makes mathematics more real and practical and not just an abstract thing. The respondent from the second group also mentioned that she benefitted a lot from it because it practically made her see that mathematics is used in daily life and there were some things that she had never thought had mathematics involved for example the bicycle parking lot. It made her get an insight into what school heads and governors do before some projects are being done. And after

doing this kind of activity mathematics is becoming more and more important to her because she now sees the practicality of mathematics.

Excerpt 4.5.2.2.2

I: what are some of the benefits that you got from the activity?

R2: like again it helped to understand the value of math and why it is important we focus so much on it because math is all around us. Like it is everything in the day to day life, it's somehow connected to math, so I feel being able to see for ourselves just how much math matters. It made math make sense.

I: don't you think it's because you don't go out to do tasks that is why you think mathematics is abstract?

R3: yeah. Because I will be more motivated to learn because I know how to use it in real life instead of just using it in a book and don't see the point of doing those tasks.

Math trails made mathematics meaningful to the participants. This is because the participant think some mathematics is irrelevant and some also helps understand the mathematics learnt better. Math trail can also be an alternative way of teaching and learning for teachers and students. Theory is done in the classroom and if possible the math trails activity can be done as practical activity. This will help the students understand the math concepts or theories learnt better.

Excerpt 4.5.2.2.3

I: so what can you say about math trail in general?

R2: it's a great way to learn math, it's a great way to understand math, it brings a lot of meaning to math and personally I felt like most of the students liked it but of course, I can't tell for everyone. But generally, we all had fun doing math outside of the classroom. So if this is worked upon to be included in the curriculum it will really benefit we the students.

I: were the mathematics involved more or less? Do you think we should have included more mathematics or we should have reduced the mathematical content? Or do you think we should have introduced that you have learnt only?

R4: yeah it should include the topics we've been through so that we can get the understanding quite well and also see the tasks done from a new perspective by doing it outside the classroom.

Fun Activity

Math trails activities make learning fun. As students walk around and work, the airy space, the discussions, the measurements on the ground, counting altogether makes the activity fun. It makes students feel like an educational trip although they are just within the school compounds.

Excerpts 5.5.2.2.4

I: what are some of the benefits you got from the activity?

R3: it was fun completing the tasks, doing it in a group, I don't really know if these are benefits.

I: so what can you say about math trail in general?

R2: it's a great way to learn math, it is a great way to understand math, it brings a lot of meaning to math and personally I felt like most of the students liked it but of course, I can't tell for everyone. But generally, we all had fun doing math outside of the classroom. So if this is worked upon to be included in the curriculum it will really benefit we the students.

I: did you benefit from the activity?

R4: yeah, I got to move about instead of just sitting in the classroom and it was fun.

In summary, the math trail activity was fun and relieved them of the normal classroom environment.

4.5.2.3 Opinion of the participants regarding the math trail

The participants had similar opinions about the frequency of math trail. Although the math trails activity made mathematics meaningful and real to most of the participants; the participants were not willing to have it too often. The participants were willing to have the math trail once in while.

I: so do you think this should be added to your curriculum?

R2: oh yeah, definitely. But I don't think we have to do it like every week, but once a month or once every two months. There could be more like physical and practical math, go outside and try

to solve math in the real world because it makes mathematics more important and valuable to us. So probably after learning a new concept, we can go out and do it.

I: so would you like it doing mathematics outside the classroom?

R4: yeah, but not all the time, but once in a while is fun.

From R2's opinion, the math trail activity can be used as a form of assessment.

4.5.3 The teacher's challenges with GPS-based math trail

The level of difficulty

One of the difficulties the researcher encountered was the researcher's thought about what students were going to perceive as doing mathematics. As the researcher included tasks such as counting and measurements, the thought about whether students would regard that as math came to mind. However, such kinds of tasks could not be eliminated because, estimations and actual measurements were to be done as part of the math trails activity. R5 did not consider counting of the bicycle parking lots as math because that task was very basic. According to R5, when the mathematics tasks are difficult and challenging, that is when you feel you are doing mathematics. However, this was the perception of R5.

R7 also had a similar perception about the math trails activity. R7 thought and felt some of the assignments in the math trails activity were not needed. According to R7, the teacher or researcher could have provided certain kinds of information in the tasks and then students could sit in the classroom and solve the tasks without having to walk around for certain kinds. An example of such kind of tasks was the counting of the bicycle parking lot. This was a challenge I encountered while designing the tasks was how special or how different are these tasks from the tasks given in the classroom. I s asked myself if some tasks be done while in the classroom?

Technical challenge

Another major challenge faced by the researcher was finding the best spot for getting the points awarded for finding the location. While piloting the KKG math trails, the researcher and the participants of piloting came from the same direction. Due to this reason, the participants always had points for finding the location when they were a couple of meters away from the actual place to carry out the tasks. However, the case was different for the students for the first-year students of KKG. The participants of the first case came from a different location opposite to where the

participants of the pilot study came from. Hence, although the participants of the first case were at the right location, they needed to walk some steps further before they could get points for finding the right location.

Excerpt 4.5.3.1

I: so what can you say about the activity that is the math trail in general?

R5: I would say the weather was the most horrible factor, I felt like the measuring tasks and the counting tasks were just useless. Because we all know how to measure and count, its just basic math. But for other tasks like the circumference of the circle, and the slope, we had to think and that was when we were doing the real math and was useful. Because you have to think how am I going to do this thing and not just some straight forward, tasks.

I: was the activity useful?

R7: in my opinion, for me, it will be more effective to sit in the classroom, because if you give more information on what is outside, it can be done in the classroom. With the parking thing, you had the task that you just have to count the total, so in the class, you have counted the total and state it the question for us to do the rest of the tasks in the classroom. Because those who actually work with mathematics don't go outside doing these counting and checks outside. The plus was that you are moving so you don't sleepy as you would when working in the classroom, and would also love it if we could run from post to post because I love sports.

In addition, the planning of the math trail activity requires time and creativity. Finding of a perfect location filled with math concepts requires time. For example, you can find a location with some math concepts, however, that math concepts might not be the desired learning outcome for the teacher. It takes time, patience and creativity to fish out the desired mathematical concepts at the chosen location.

Getting used to the Actionbound software was a challenge. This was an app I had to learn on my own to explore how it worked. This also takes time, since you explore and experiment to find out how well the app worked. Putting of the designed tasks, the answers, putting of pictures, finding

of the perfect spot for the participants to get the points was a great deal. Even after trying out the math trails several times, the participants had challenges of getting points for finding the location.

Also, as a teacher, I had little control over the students sharing of answers. For example, from the interview, it was identified that, some students took measurements from other groups. As teacher you can only give instructions, however due to the absence of the teacher, students can copy answers.

As a teacher who is used to giving explanations and demonstrations, it became a challenge standing quiet when students struggled with understanding the tasks. I had to step in to help them.

4.5.4 Benefits the teacher derived from the math trails activity

Designing math trails activity helped me as a researcher to gain more knowledge about how to link the classroom mathematics with the real world. As a teacher, I was used to giving students word problems in the classroom. However, after this experience with math trails, I have more insight into have hands on activities in mathematics.

Math trails activity has also helped shaped my way of formulating tasks. That is, not putting in too much information as well not too little information, but sufficient information to help the students understand what they are supposed to do.

Math trail provide opportunities for different methods of teaching and assessment. Through math trail, students learn practically outside the classroom. This helps the students to connect the classroom mathematics to school.

Through the Actionbound app, the teacher communicates indirectly with the students without speaking, or using a workbook. Tasks information, hints, correct answers, and thigs needed for the math trail are all put into the Actionbound. Hence the Actionbound app plays role of a teacher.

The math trail activity made the students happy such that, the students were focused on completing the tasks and if not for the rain that set in.

4.7 Conclusion

From the excerpts drawn from the interview, the following conclusions can be drawn from the first case;

Time factor

Participants' perspective:

Bad weather condition

Insufficient task information, and

Provision of relevant materials were the challenges faced.

Benefits from students' perspective:

Conclusions in benefits drawn from this case study are;

Math trails makes mathematics meaningful

Math trails helps students realize the reality of the math concepts

Math trail is a fun activity

Math trails promotes teamwork

Students opinion on math trail:

Math trail shouldn't be done frequently

Teacher's perspective on challenges:

Based on the teacher's experience from designing the math trail activity, the following conclusion on challenges are drawn,

Level of difficulty

Participants challenges:

Finding the location and technical challenges

The use of mobile software

Finding the right locations

Time and creativity

Inability of teachers to actively engaged in the learning process.

Teacher's perspective on benefits

The benefits the teacher derived in this case study are;

Teacher gains in-depth knowledge of how to connect mathematics to reality

Math trail activities provides for different teaching method.

Providing substitute in the absence of teacher (Actionbound)

Making students happy while partaking in math trail.

4.8 Recommendations for next case study

Based on the results from this data collection, the adjustments were made to the GPS guide in the Actionbound app. This will make finding the locations of the tasks easy and getting the points awarded for that will not be a problem. In order to fix this, I will have to consider all possible angles the students will come from and try to fix the area for getting the points. Also, using clearer and simpler expressions will be highly considered.

In addition, in order to get rid of the participants' feelings about what is basic mathematics and what is actually mathematics, the level of difficulty of tasks could be adjusted. For example, counting is also mathematics. However, for a five-year-old in kindergarten counting would not be just a basic mathematics but quite tough activity as compared to High school students who thinks counting is not mathematics because it is basic according to his standards

CHAPTER 5

Report of the second case the pre-service teachers' math trail at UiA

5.0 Introduction

This chapter describes the second case study of the math trail activity which was carried out with the 4th year pre-service mathematics teachers. The chapter looks at the participants and settings, the tasks used for the data collection, the interview guide and the results from the data collection. The main part of this chapter holds the results and analysis based on the interviews held and on my experience during the planning and carrying out of the activity.

The study of this second case was done using an improved planning for the first case math trails activity. The tasks, math trails activity, and interview guide used for this data collection were an upgrade of the first case's instruments. The purpose of the changes in the second case study was to reduce some challenges which impeded the smooth navigation, and to meet some suggestions that the students made.

The data collection of the second case was done through interviews with the participants. However, before the interviews, the participants had partaken in the math trails activity.

5.1 Participants and settings

Pre-service mathematics teachers in their 4th year taking a 5-year mathematics teacher education program at 1-7 level from the University of Agder participated in the data collection. The students took a course on problem based teaching, in which the lecturer saw the math trail as an appropriate activity. As future teachers, it would be good to know that an exercise of this nature exists in which they take the pupils outside of the classroom to learn and explore mathematics in relation to reality. For my research, this group of future teachers enabled me to find out the challenges in this activity, the benefits they derived, but they could also offer their thoughts on the math trails as well as their recommendations if they are to conduct such kind of activities. The participants of this data collection were above 20 years old and could decide for themselves whether to participate or not. They were informed about the master thesis and its purpose, what they were going to do and what the information obtained from them was going to be used for.

There were 16 students in the course. . A week before the activity, I visited the class to give an introduction. On the day of the introduction, there were 10 students and all agreed to participate. The students were put in groups of two which made groups of five in total, however, one group had three members because the lecturer of that course joined the activity. Students were informed

on the day of introduction what they were going to need, what the researcher was going to provide for them and what they had to provide on their own. The things needed were; a measuring stick/tape, calculator, pen, note book, charged mobile phone with internet and the Actionbound app. Out of these tools, the researcher provided measuring sticks and books. After the students got to know the things that were needed for the activity, some decided to come along with personal measuring tape instead of using the stick. Unlike the first data collection, the participants of this case downloaded the app on the day of introduction and tested how they were going to use the app. So they were already prepared and knew how they were going to start the activity. Also, emphasis was made on the participants ending the bound by pressing the finished bound which they duly did. However, students were not informed about the particular tasks they were going to do, or what subject areas they were to revise for the activity.

A few days before the planned activity, the weather predictions foresaw very wet weather at the time of the activity. In coordination with the teacher, the activity was then deferred by one week.

On the day of the actual activity, papers with scan codes were printed for the students so they would get access to the math trail in the Actionbound app. In order to avoid students being crowded at the nearest location, sheets with task titles were distributed to the groups, so the name of the task location they had on their sheet was where they began. After the activity, the participants delivered the note book to the researcher and then the activity ended. The average time used for the math trails activity was about 1hr10minutes; the least time used was 50 minutes 20 seconds as well as the most time used was 1hr47min32secs. I could see this information as designer of the math trail in the Actionbound software.

5.2 Tasks

5.2.1 Task description

The tasks used for the data collection were 9 in total and they were grouped under five locations namely; the bicycle parking area, the white building, the diversity and fire escape and the Oddernes cemetery, (Appendix 5a). The bicycle parking area had three sub-tasks, the white building had two sub-tasks, the Oddernes cemetery had two sub-tasks, diversity had one sub-task and fire escape had also one sub-task. Out of the nine tasks, the diversity task and the fire escape tasks were

adopted from Nils Buchholtz and Pauline Vos (not published) UiA math walk tasks. The rest of the tasks were originally made by the researcher with inspirations from Nils Buchholtz and Pauline Vos UiA math walk tasks and modifications to tasks made after the first data collection. The mathematical concepts needed for the tasks were measurements, counting, area, ratio, angles, fractions, percentages and estimations. The table below describes the locations, tasks and their desired learning outcomes.

LOCATION	TASKS	DESIRED LEARNING OUTCOME
The bicycle parking lot	There are 1600 students and 200 teachers at the KKG. If 80% of this population decides to come to school by bicycle, how many of these bicycle parking lots will be needed?	Participants are able to apply their knowledge in percentages. The participants are able to make estimations and also have a knowledge about the sufficiency of the parking lot.
	Do you see the rectangular field from entrance 3.1 to 3.4? How big is this portion in metre square?	Participants are able to make estimations, by calculating the area. This will help the participants to have a view of the number of people that can fit into the area while observing 1 meter distance.
Finding locations	All tasks regarding finding location	Participants are able to navigate with the help of GPS.
The white building	b. building regulation demands that the slope of a wheelchair is not steeper than 1:12. Is the	Participants are able to apply trigonometric ratios. Participants become aware of the safety of the slope of the wheelchair ramp.

	wheelchair ramp the white building designed to suit this regulation? b. What is the slope of the ramp in percentage?	
	do you see trees in front of the building of approximately the same height? Estimate the height of this tree.	Participants are able to make estimations
Diversity	16 August 2019, a pedestrian crossing in rainbow colors was inaugurated to celebrate diversity at UiA. Surveys in different countries say that the percentage of LGBTI+ people among any population is 4-7%. At UiA, there are 13 690 students and approx. 1500 staff members. Approximately, how many students and staff at UiA will be LGBTI+?	Participants are able to make estimations through approximations. Participants are able to apply percentages. Students realize that there are students and staff who are LGBTQ+.
The fire escape	The 2nd, 3rd and 4th floors of Building D have an emergency escape on the east. Imagine there are 200 people on each floor, and there is a sudden emergency that requires all to take the staircase.	Students are able to apply arithmetic operations. Students realize how long it will take for a specific number of people in the library to get out

	How long will it take for 600 people to run down?	through the escape in case of an emergency.
The Oddernes cemetery	This is the Oddernes cemetery closer to the UIA bus stop. How wide is the space from the line on the last burial to where the yellow signboard? a. How many graves can fit into this yard? b. From 2017 to 2019, 387 graves have been buried in the new oddernes cemetery. how many years will it take for this yard to full?	Students are able to estimate the number of graves and also forecast the number of graves that can be dug at the calculated area.

The tasks were made with reference to Ärlebäck and Bergsten's (2013) characteristics of realistic Fermi problems. The characteristics are stated below;

Their accessibility, that is can the task be solved by every student when the difficulty level is adjusted and also approachable by every student. The students do not really need any pre-mathematical knowledge;

· Their clear real-world connection, that is being realistic;

· The specifying and structuring of the relevant information and relationships needed to tackle the problem;

· The absence of numerical data, that is the need to make reasonable estimates of relevant quantities;

· The inner momentum to promote discussion, that as a group activity they invite to discussion on different matters such as what is relevant for the problem and how to estimate physical entities.

5.2.2 Tasks' locations

The nine tasks were found at three major sites, that is the UiA, Kristiansand Katedralskole Gimle (KKG) and Oddernes Cemetery. At KKG there were two task locations; the first location was at the school's entrance 3.1 and the white building beside the volleyball pitch. The second site was UiA also with two locations; the first location was at the colorful pedestrian crossing at the main entrance of the university, and the second was at the fire escape of the library which is close to the old SiA office. The third site was at the Oddernes cemetery with only one location. Also regarding the accessibility of these locations, they were located at places that students could access with the help of GPS. The tasks were located at places where many people pass by and it would be very difficult to get lost or not have internet access.

The tasks designed were put in the Actionbound. This was an improved edition of the KKG version and was titled UNI KKG trail.

5.3 Interviews and interview guide

To find out the benefits and challenges of having a math trail activity, a semi-structured interview was conducted after the participants did the math trail activity. The interview was scheduled to happen between one and two weeks after the activity. Due to COVID-19 issues, we planned to have the interview on zoom although the ban on social distancing had been lifted. Another reason for having the interview virtually was that the students were having their off-campus teaching practice and would be away from campus and the researcher didn't want the time for having the interviews to go beyond the scheduled week.

In this case study, some of the groups had one participant representing the group for the interview. While in other groups, all the participants of the group decided to share their experiences during the interview. The first group (T1 and T2), the second group (T3 and T4) interviews were a group

interview. The third (T5) and fourth (T6) group's interview were conducted with group representatives.

There were 6 interviews that were supposed to be done, however, it turned out to be five interviews because no one from a particular group showed up for the interview.

The researcher took the role of the interviewer for the interview. Before we began each interview, the researcher explained to the interviewees some terms in the interview guide and also how the interview was structured.

5.3.1 Interview guide

The interview guide used for this cases study consisted of four parts, the first was the introductory part, the second part asked about the challenges, the third part asked about the benefits and the third part was about their opinions on GPS-based math trails. There were 24 questions in total, the first 20 questions were general and were to be asked every interviewee but the last four questions were to be asked to the lecturer who joined the math trails activity. The interview guide can be found in Appendix 5b.

Some questions in the interview guide are stated below together with the purpose of choosing those questions.

1. Was it difficult finding access to the place? Which was the hardest, and why? Which one was easiest and why?

The reason behind this question is that math trails dealt with finding mathematical tasks at some specific location. Difficulty to find these locations or the participants inability to find a location becomes annoying, demotivating and at the worst the purpose of the activity will not be realized because they couldn't find the location. Therefore, being able to find the locations with little or no difficulty is a necessary thing to consider and also, a possible challenge the participants may encounter.

2. Was it difficult trying to understand the tasks? Which one was hardest and why? Which one was easiest and why?

One possible challenge that participants of a math trail can face is not understanding what they are supposed to do at the found location. This could come about as a result of some information missing in the description or scanty task description.

3. Was it difficult finding the mathematical idea behind the task? For which task was it hardest, and why? For which one was it easiest and why?

Were the tasks related to their previous knowledge in class? Had they learnt anything about the concepts that they were supposed to use in answering the tasks? Since one of the requirements of this activity was for students to use already acquired mathematical concepts, hence, if they have no idea about the mathematical concept to use, then it becomes a challenge for them.

4. Was it easy to understand the terms used in the question? For which task was it hardest, and why? For which one was it easiest and why?

Again, since students are on their own without the supervision of the researcher or without explaining anything to them, it will be necessary that task description is simplified, as well as terms used in the task description are terms that are familiar to the participants. In the first data collection, some terms were used in some of the questions which were unfamiliar to the students and it became a challenge for them because they didn't understand the question or know what mathematical knowledge to use as a result.

5. To what extent were the materials provided to you relevant for the activity? Did you need any special material which you did not have at hand and that made your work difficult?

The activity involves actual measurements, calculations, estimations as well as modelling, hence the participants will need such kinds of tools or equipment to make the activity easier for them. Hence they will be provided with tools that the researcher deems fit for the activity. However, will the participants need tools other than what they were provided with, or will they be provided with tools that are irrelevant to the activity, that will pose a challenge for them, because they will need some tools for the activity which may not be present.

5.4 observation from the researcher

The researcher was the observer for this case study. The unobtrusive method of observation was employed for this case study. The observation was unobtrusive because I did not interrupt or try to help the participants during the observation. However, during the activity; I met a group who shared their experience on finding the location without getting the points. They had walk some meters backwards to fall within the ring for getting marks.

Unlike the first case study, the groups were not crowded at a particular location. They were scattered among the locations. I stood at a point where at least every group passed. I did not observe participants experiencing difficulties. From my observation, it was a well organized math trail.

5.5Results and findings

5.5.0 Introduction

This section will look at the results of the data collection. Issues that will be looked at in the results will be focused on the benefits and challenges that the students encountered while having the math trails activity. Summary of the results are presented in tables. The thematic analysis was employed to arrive at the results of this case study.

In this case study, the participants played double roles. First as students carrying out math trail activity and second, as teachers carrying out math trail activity. Their opinions and suggestions are included in the teachers perspective on benefits and challenges of having a math trail activity; as well as students who experienced math trail activity.

Findings	Codes
Accessibility	ASS
Finding the location	FTL
Getting points for finding the locations	PFTL

Understanding the task	UTT
Provision of relevant materials	PRM
Weather challenge	WC
Good weather	GW
Bad weather	BW
Fun	FUN
Meaningful mathematics	MM
Understanding mathematics concepts	UMC
Teaching strategy	TS
Simpler tasks	SP
Introducing of math concept	IMC
Prepare worksheet for students	PWS
Difficulty understanding the tasks	DUTT
Easy understanding the tasks	EUTT
Difficulty in estimations	DE
Precision of answers	PoA
Scanty information in task description	SITD
Ways of using math trails	WUMT
Safety	SAF
Lacking math concept	LMC
Guessing	GUE
Physical activity	PA
Number of tasks at one location	NTOL
Team work	TW
Discussing solutions in class	DSIC
Finding suitable content for math trail	FSC
Reality of mathematics	RM

Large number of class	LNC
Supervision	SUP
Revision before a math trail	RBMT
Traditions	TRA
Alternative for class exercise	ACE
Knowledge about the environment	KATE
Difficulty putting numbers in the app	DPNA
Avoid provision of answers	APA
Creativity and diversity of tasks	CDT
Group formation	GF
Challenges	CHA
Benefits	BENE
Opinion	OPI

Table l: the codes and the themes they fall under

THEME	CODES	L	PSG1	PSG2	PSG3	PSG4
CHALL	ASS	ASS	ASS			ASS
	SAF	SAF	SAF			
	FTL	FTL	FTL	FTL	FTL	FTL
	GPFTL	GPFTL	GPFTL	GPFTL	GPFTL	GPFTL
	DUTT		DUTT			
	DE			DE		
	LMC		LMC	LMC		LMC
	SITD		SITD	SITD	SITD	
	GUE			GUE		GUE
	GW		GW	GW		GW
	BW	BW	BW	BW		BW
BENE	MM	MM	MM	MM	MM	

	UMC	UMC			UMC	
	PA			PA		
	IMC	IMC			IMC	
	FUN	FUN	FUN		FUN	
	PRM	PRM	PRM	PRM		
	PA		PA	PA		
	NTOL		NTOL			
	TW		TW			TW
	FSC		FSC		FSC	
	RM		RM	RM		RM
OPI	LNC		LNC			
	ACE		ACE			
	RBMRT			RBMT		
	KATE		KATE	KATE		
	PoA			PoA		PoA
	DPNA			DPNA		
	APA			APA	APA	
	SP	SP	SP			

Table m: the codes and the themes they fall under

The table m presents the codes and themes associated with them. The PSG 1-4 represents the pre-service teachers' groups that participated in the interviews. The L represents the teacher of the participants that joined the math trail. The empty cells means that, the a group did not connect to any particular co de.

5.5.1 Challenges

The first challenge that was looked at was finding access to the location. The majority of the answers provided by the students showed that finding the tasks' locations was not difficult. This was as a result of the GPS guide adjustment that was made in the app. The researcher piloted the

tasks once more and looked at the circle in which all the participants coming from all angles will fall in, in order to receive the points. However, some of the participants still faced some challenges with getting the points after they had found their locations.

5.4.1.1 Excerpts from the interview (Not getting the points for finding the location).

I: was it difficult finding access to the place? Which was the hardest, and why? Which one was easiest and why?

T5: I think we did find some difficulties especially when we were supposed to go to the church, we thought it was close to the yellow sign and the task at the white building we got the points for finding the location quite early but the building was a little further but not too far. The challenge is, it wasn't exactly at the location where the points were awarded. accuracy of finding the spot, and not getting the point)

I: so it means you got to the place but getting the point was the challenge.

T5: yes, because we got to the white building, but we had to come back to some point before we could get our points for finding the location. Finding the white building wasn't the problem actually because we could see the picture of it in the app, but getting the award for finding the location was the challenge because we needed that to continue.

From excerpt 5.4.1.1 it is obvious that finding the location of the tasks wasn't much of a problem, however, getting the points for finding the location was a challenge for the students.

Regarding the difficulty in finding the task locations, one of the groups couldn't find the KKG bicycle parking lots tasks location because they perceived a different location with bicycle parking lots. Another reason why they landed at a different location was a result of them reading hurriedly through the task description. In expressing the difficulty in finding the location, students wholly agreed that it was their mistake.

5.4.1.2 Excerpts from the interview

I: was it difficult finding access to the places?

T1: no I think it was easy, the GPS told us where we were going and how far we were from our targeted location. That was very great.

T2: we actually misunderstood the bicycle parking lot, we hurriedly read the description of the location, so we went to the bicycle parking lot at the entrance of UiA but later we realized that it was at KKG so we had to go back. It was our mistake.

One of the challenges that were identified, and mentioned by all the interviewees was accessibility to the fire escape. The students wanted to experiment for themselves on how long it will take for them to get out during an emergency. However, they could not get access to the staircase. The first group to experiment with this got stuck in and was able to get out after several attempts, however, none of the groups which came later could access it.

5.4.1.3 Excerpts (Accessibility of task locations)

I: so apart from the questions that have been asked about the challenges, do you encounter any challenges apart from the ones that have been asked?

L: one practical problem was at the emergency fire escape. We were the first group and we solved the task, but I don't any other group can solve it after us. Because after us, the door was locked. So they may not be able to do the experiment of running up and down the stairs at the emergency exit.

Another challenge that some of the participants faced was the imprecise nature of some of the tasks, particularly the task at the cemetery. This was due to insufficient information provided and therefore led to the confusion of the students as to the actual area they were to make the measurements.

5.4.1.4 Excerpts from the interview (Imprecise description of task and answers)

I: was it difficult trying to understand the tasks? Which one was hardest and why? Which one was easiest and why?

T5: not so much, but the one at the church was a little bit hard, we were supposed to measure the field, but we didn't quite understand where we were supposed to start with the measurement. wasn't from the nearest end to the yellow sign board or from the farthest end to the yellow sign board. I have sufficient task description

I: so you couldn't figure out whether you were to begin the measurement from the nearest grave or from the farthest end of the graveyard.

T5: yeah.

I: was it difficult to find the mathematical idea behind the task? For which task was it hardest, and why? For which one was it easiest and why?

T6: no, not at all. I really liked the ideas of all the tasks, the fire escape task was a bit difficult to estimate or calculate, because we didn't have access to it and it was pure guessing. But I do like the fact behind all of the tasks and how everything made sense mathematically.

I: if you are to plan such an activity for your students, what would you consider? If the participant does not answer spontaneously, a hint can be to think of group composition, avoid phones in primary school, and avoid competition between pupils.

T4: Specific questions and accurate information on the answer page are important. For example, the problem by measuring the tree, then the answer page should tell us whether we should state the answer in cm or m. The problems should also be made so that all students can experience mastery. You may want to focus on customized training, and for those who need extra challenges, this can happen in the classroom.

For the fire escape tasks, most of the groups complained about the difficult nature of the questions asked and also, how they didn't see the tasks as related to mathematics but rather a task which required guessing as their final method for answering the question. The reason why they couldn't experiment with the fire was that after the first group to be there closed the door, no one could open it from the outside and they even struggled a little to open it from the inside. This created awareness to the researcher that, safety issues should be considered when planning math trails activity since it could pose safety hazards for students or other participants of a trail. Another challenge that was realized in the fire escape task was about looking at the accessibility of task locations. From the interview it was made known by the interviewees that they wanted to experiment with the staircase in the fire escape however, they couldn't access the staircase.

5.4.1.5 Excerpts from the interview (difficulty understanding the tasks)

I: which tasks were difficult to understand?

T4: I think the fire escape tasks were hard. It was a lot of estimating and we didn't know how high the stairs were, so we were a little bit unsure when we were answering the questions and the information was not also enough.

I: was it difficult finding the mathematical idea behind the task?

T3: yes, I think so.

I: which of the tasks was difficult getting the mathematical idea behind it?

T3: it was difficult to understand the tasks at the fire escape and we also had a problem with the white building task with the tree, because when we were estimating how high the tree was, we found out it was a little bit more than 300cm and the answers were I think only from zero to two hundred. So we didn't know if it in meters or centimeters. Then we assumed that the answers were in meters, but we were wrong, and we couldn't really understand what you were asking about.

One of the major challenges that interrupted our activity was the weather. The day for this data collection which was scheduled on a Friday had to be cancelled because of the weather, there was going to be a heavy downpour of rain. Due to this weather challenge, the math trails activity was postponed to the next Friday because there was going to be lots of sunshine. Although students enjoyed the weather, they shared how the rain would have affected the activity.

5.4.1.6 Excerpts from the interview

I: the weather was quite lovely because there was a lot of sun. I think we had to change our day for the activity because it was going to rain heavily on that day. But then do you think it would have been okay if the weather was snowy, rainy or anything otherwise do you think it will be a challenge?

L: maybe when it is raining and cold or slippery, or snowy, the time we spend outside might be limited. Because if you are doing this task with young kids we don't want them to get wet or cold so it may not be the best to have it in bad weather.

5.5.2 Benefits

One of the benefits that cut across for all the participants was that the math trails activity is a fun way of learning and doing mathematics. As the students walked, finding the task locations,

discussing, getting the answers right, and getting them wrong altogether made the activity a fun one to do.

According to the responses to the interview questions, math trails activities made mathematics meaningful since the students applied the mathematics learnt in the classroom in the environment. When asked L, he opinionated that, math trail is one of the best ways in making students understand the mathematics concepts learnt in the classroom easily.

Also, one of the benefits of having a math trail is that it can be used as a teaching strategy. L mentioned math trails can be used as a teaching strategy, especially for teacher education students.

I: so would you consider using a math trail activity?

L: yes. Certainly, my group members enjoyed doing it because they told me. They were out in the nice weather doing mathematics and learning at the same time. So next year I may do this as a teaching strategy with my pre-service teachers' students.

I: so how beneficial do you think this activity was to your students?

L: it was beneficial, they learnt another teaching strategy as future mathematics teachers

I: do you think this activity will make students understand some of the topics that you learnt better?

T3: yes, it is possible. You need to know the shape of the area, and that is geometrical, and the shapes of the grapes and all the measurements and estimations were very good. It is a good alternative for classroom learning because the pupils are able to see for themselves and not just draw rectangles in their books.

T3 in her opinion suggested that math trail can be used as an alternative for a classroom exercise.

I: as a teacher would consider this math trail activity?

T4: I agree with T3 and I think this math trail is good, because you don't have to sit in the classroom and do tasks. You also go to a new environment and the teaching method also changes.

Another benefit of using math trails is that it makes understanding some mathematical concepts easier.

I: to what extent do you think that will assist pupils to understand some mathematics topics learnt?

L: 100%. It will help them understand proportions, measurements of distance, time, area etc. makes those concepts meaningful.

Math trails activities help students to get a better connection between what is done in the classroom and the real world.

I: to what extent do you think this activity will help some mathematical topics like geometry and measurements be better understood?

T1: I think they benefit from actually taking the measurements themselves, and not only using centimeters but then they get to see how big it actually and that is interesting.

Another benefit of the math trails activity which was mentioned by almost all the groups was that math trails not only help in mental and academic activities but also their helps them physically as they learn while moving around.

I: are there any other benefits that you derived apart from the ones mentioned?

T1: physical activity is one of the beneficial sides of the whole math trail activity. And for children that have energy and difficulty sitting at their desk, it will help them move their body and I think they will like that. It makes the pupils physically active.

I: as a teacher would consider this math trail activity?

T3: yes, I will use some of your tasks but will also use different questions. I think it is good that the pupils learn around and also use their bodies. If I am to plan a trail, I will consider percentages of geometrical fields.

Another benefit that the participants derived from the math trails activity were that, it promotes teamwork as the group members are involved and everybody works for their group to get the right answers.

T1: it was fun to collaborate with each other and not doing it alone.

T2: we were three in our group and that was a great amount for these tasks. Someone can write, other can measure, and another can count. And everyone in the group had something to do. And it really promoted teamwork.

In addition, another benefit of math trails activity Is that it helps students to get more knowledge about the environment they live in.

I: Which tasks are beneficial to pupils? How are they beneficial to pupils?

T4: The task at the cemetery is a good task for students, it requires at least mathematical understanding. The task at UiA in the colored transition field is also an interesting task for the students who can also provide more knowledge about the society we live in, today.

Last but not least, the benefits that were mentioned by T6 in the interview are that math trails promote modelling and also help students become task creators.

I: to what extent does this activity assist pupils to understand some mathematical topics like geometry or measurement better?

T6: I feel so. I feel like making them see shapes and paradigms in everyday life will make them more curious to be making their own little tasks and solving them mathematically and also sharing it with others will be fantastic.

I: what are other benefits and limitations of my KKG-math trail you derived apart from those mentioned?

T6: one of the benefits for me is that, students can take pictures of their solutions and then we can discuss in class, the different strategies they used in deriving their answers. One limitation will be that if you have a large class managing the groups will be kind of hard, but we can as well limit the distance and maybe have it at a playground or around the school.

5.5.3 Opinions of the teachers

The pre-service teachers also suggested ways of making the math trail beneficial to students and teachers. Aside the benefits and challenges mentioned above, this section looked at the opinions of the teachers.

A teacher suggested that, to make math trail activity a modelling activity, the gaming aspect and the provision of answers need to be avoided. In place of that, discussion of every group's solution in class will make students share ideas. T6 was of the opinion that getting answers wrong and getting zero points was demotivating. T5 also share her opinion on avoiding the

gaming part. In T5's opinion, the gaming aspect would take the focus on mathematical modelling and shift the focus onto competition. T1 and T2 also mentioned the discussion of solutions derived in class. In addition, T2 suggested that, each group solves a task. L suggested giving of worksheet to the students will help in mathematical modelling.

In addition, T6 suggested that, having pupils supervised is very important. However, a teacher will face challenges of getting supervisors for a large class. L also suggested, getting extra help from other teachers for students management.

Informing of students about the content area the math trail activity is key. This will help the students prepare themselves and know how to solve the tasks well. This was T4 opinion regarding the preparation of students before a math trail.

Take note of the traditions of the community. This will help avoid committing abominable or insolent act towards the community. For example, T3 mentioned that, having a fun activity at cemetery was a sign of disrespect to the dead. I as the teacher was not aware of that.

Putting too many tasks at one location will make a math trail boring. T2 suggested that, spreading of the tasks will help make the activity interesting.

5.6.1 Challenges faced by the researcher

Due to the experience from the first data collection, not many challenges were encountered. The only major challenge I had was fixing the appropriate place for getting the point for finding the location. However, as stated earlier, when it comes to having a GPS-based math trails activity, one of the goals is finding the location and not just awarding points for finding the location.

Just like the first case, the weather was a challenge. As mentioned in 5.1, the weather predicted that there was going to be rained on the first date scheduled. This affected the math trail activity, and had to be postponed to the following week.

5.7.2 Teacher's benefits of designing a math trail

Redesigning the activity and rewording the task descriptions helped to improve how I designed tasks. That is, not putting too much information as well as not too little information. Also as person

who studies within the walls of UiA, I became a little bit informed about the campus. That is, I got to know the number of minutes it will take for people to escape the library in case of fire.

In addition as mentioned by L and other participants, the math trails activity can be used as a method of teaching and assessment. This kind of assessment can be done from elementary school level to the university. This is because, this is a mind opening activity in which the teacher gets to explore more about how the mathematics thought in the classroom can be used in the daily lives of students.

Math trail planning will help teachers to become less dependent on textbooks, but rather become task creators. By doing this, teachers will be able to connect mathematics to the direct school environment. Designing of tasks for math trails by a teacher will help tailor the tasks to the level of the students.

Through the use of app, the teacher can get students to the desired location without having to be there physically to explain stuff to the students. This is very pleasant to students ,as students get to walk without the presence of a teacher.

5.8.1 Conclusions

Student's benefits

In general, this math trails activity was a great one. Issues such as the GPS was inaccurate, I couldn't understand the tasks were seldom encountered. Although I tried as much as possible to reduce the challenges that students may face while doing a math trails activity, the participants still encountered some challenges

Focus on modelling rather than answers and points

Supervision of pupils

Informing the students to revise the math contents in the trail

Safety and accessibility issues were the least expected challenges in this math trails activity. However, some of the participants got stuck in the fire escape while others couldn't get access to the building.

Also, a group was confused with the cemetery task description. This was because, the participants of that group couldn't figure out where exactly to begin the measurements.

Weather was a challenge for this activity. The date for having the math trails activity was changed because it rained throughout the day. Due to that it had to be moved to another day which was bright and sunny.

Benefits:

Regardless of the challenges that were encountered, the participants also benefitted from the math trails activity. The benefits the participants derived from the activity are stated below.

Math trails activity makes learning of mathematics fun.

It also helps to make the understanding of learnt theories easy. This is because, math trails activity provides the opportunity to use the concepts learnt in real life. And thus help students to model mathematically.

The math trails activity can be used as a method of teaching and assessment.

Math trails activities help promote teamwork.

Math trails activity also helps students to be physically active since they learn by moving around. It helps improve their psychomotor skills.

Math trails will help students to become informed about the community or environment they live in.

The Actionbound app replace the teacher's role

Opinions:

5.8.2 Recommendations

The major recommendation based on this math trails activity is that sites or locations chosen for a math trail activity should be thoroughly experimented. This is to prevent casualties from happening to students or participants especially if they are young.

Also, precise description of tasks should be looked at when designing a math trails activity. This is to prevent the participants from needing extra explanation from the teacher or designer. everybody can count, hence, counting is not mathematics.

CHAPTER 6

Discussion.

This chapter presents a discussion of the research findings. The discussion is done with reference to the literature review and the theoretical framework. The challenges the participants faced are discussed, followed by the benefits the participants derived. The challenges faced by the teacher and the benefits the teacher derived are also discussed. The discussion was centered on the first and second math trail cases. The discussion of both the students section, as well as the teachers' section are influenced by the pre-service teachers and lecture's responses. This is because, the pre-service teachers together with their lecturer played a double role. This inclusion was done to strengthen the reliability of this study. Also, the pronoun 'he' and 'she' are used to anonymize the participants.

6.1 Challenges students face while doing a GPS-based math trail

The purpose of math trail in this study, was to serve as an alternative role for "dressed up" tasks. That is the primary purpose was to establish the reality between classroom mathematics and the world. However, for a student to have a perfect math trail, obstacles that will make a math trail unsuccessful need to be considered. This study sought to find out such challenges. The challenges of this study are discussed in the sections below. This sections discusses the challenges that the students of this math trail faced during the math trail activity.

6.1.1 Getting points for finding the location

Math trail is a walk to discover mathematics (Shoaf et al., 2004). Discovering the mathematics involves the movement from one location to the other. According to Shoaf et al (2004), in order to make sure that a math trail activity is run smoothly a teacher needs to consider the location (whether it is near, or whether students can easily find it). The tasks locations for the math trails were familiar to the students especially the participants of the first case. For this reason, although the students complained about the navigation with GPS-guide they still got to the place. This was because pictures of the locations were attached. This made the students to easily the identify the locations. This supports the suggestion made by Shoaf et al. (2004) that, the task locations should have the characteristic of the students finding it easily.

However, the points allocated to the finding of the location was the challenge in this study. The primary purpose of the GPS was to help the participants find the location. The awarding of the marks makes the activity fun. In this study the points awarded somehow shifted the focus of the students from the connecting of the math trail activity with the world to getting the points for finding the location. The students deserved the points for finding the location, since the math trail was designed to get points finding the location. Therefore the students not getting the points for finding the location makes it challenging. Otherwise, the getting of points for finding the location wouldn't have been a challenge.

In addition, the students trying to fall within the demarcated ring (see image 7.a) for points can be time consuming. The time spent for trying to fall into the demarcated area could have been used for solving the task after finding the location.

This kind of challenge is in line with the technical challenge mentioned in Mehdipou and Zerehkafi (2013). Although this challenge not explicitly mentioned by Mehdipou and Zerehkafi (2013), it fall under the category of technical difficulty. This has do with technicality because, the students were to fall within the ring to get the points.

Image 7. a

From Image 7.a every participant or every group has to fall into the ring before the points can be redeemed. However, the circle was not big enough to cover every angle from which the

participants appeared when coming to the task locations. Due to this, some participants were able to find the locations but not get the points. This happened in both cases of the KKG math trails activity and the math trail activity with the pre-service teachers. More such examples were recorded in the transcripts. This instance of a participant in a gamified math trails activity not getting the points for finding the location can make participants confused especially if the participants are unfamiliar with the location. This can pose some challenges to the participants because even though they are at the location, the GPS-based app tells them that they are some meters away from the location. When a math trail is not organized with a GPS-based app, as in Buchholtz (year) and Shoaf et al. (year), this challenge will not occur in the same way. It then depends on how the students are guided to the locations, which may bring other challenges. If the students are guided by written directions on paper, this may also yield challenges.

In addition, one of the challenges associated with the finding of the location was the participants' assumptions of knowing the location. For example, a group's presupposition of knowing the location led them to ignoring the GPS guidance to the task location and then ended up at the wrong location. However, with the help of the GPS notification of the difference between their present location and the task location, they were able to find the right location (excerpt from 6.4.1.2).

Students' presumptions of locations can lead them to wrong destinations when finding the task location during a math trail. It is important that students follow GPS guide or the map guide provided for them. following a picture alone can deceiving; especially in the case where there are similar buildings or spots. Students presumptions of task locations may lead them to the right location, however, this is not always the case. In the case where the assumed location is far from the actual location can be worrisome. Students partaking in a math trail activity should be duly guided regarding the safety in following the map to the right location.

Contrary to Mehta (2016), challenges such as unethical use of mobile phones, and poor designs, were not seen during the activity. However, unethical use of mobile phone should be considered whenever planning math trails activities, especially for high school students and elementary school pupils. To avoid circumstances of students of students' unethical use of mobile phones, school phones and tablets (if the school has) can be borrowed. This is because, phones used for solely educational purposes have certain sites which cannot be entered on the phone.

Also as mentioned by Fägerstam and Grotherus (2018), participants cheating with mobile phones was not a challenge, however, it occurred during the math trail. Other group took the measurements from other. Provision of relevant and easy to use materials is a factor when it comes to the avoidance of students cheating during a math trail. For example if students are to measure a wide area with some short sticks, then other students who find it boring doing that measurements will copy from other groups. This can prevent the student from realizing the purpose of the activity.

Provision of easy to use tools is very important, especially in the case of pupils. This is because provision of appropriate materials can affect the amount of time students/pupils use for math trail activity.

In addition, Mehdipou and Zerehkafi (2013)'s challenges of mobile learning such as connectivity to internet, battery life, screen size and key size were not mentioned by the participants of this study. Although the Actionbound app employed for this study needed internet connection for the GPS to work; situations such as the GPS not working were not encountered. This is not to oppose the connectivity to internet challenge identified by Mehdipou and Zerehkafi (2013). This is because internet connection can be a challenge in the case where students do math trail in a remote area with bad internet connections. This can be very frustrating since students will finding it difficult navigating the internet. Moreover, preparation of students before the activity is significant to avoid such circumstances. Making sure each student has a good internet and a data that can sustain them through a math trail activity is very important. However, this can come with financial difficulties if the teacher is to provide data for each student without enough data for a math trail activity.

In case, an app requires the use of internet for students have access to GPS, other learning app can be used. An example is the math city map app Gurjanow and Ludwig (2017) chose in their study. The math city app only required internet to download the math trail activity. After which the GPS could help the students navigate their way to the task locations without internet connection. This will relief of the burden of who has internet connection wherever they are during the activity.

6.1.2 Accessibility of task location

A major challenge that was faced was the inaccessibility to task locations. This situation was encountered in the pre-service teachers' math trails activity. This happened after the first group to do that task was locked up and struggled before getting out. Such kind of a challenge can cause fear and panic in the participants of a math trails activity. This would get worse in the case of pupils. Although the task did not require the participant to enter the fire escape, some students wanted to experiment with how fast they could run the stairs in order to solve the task. Hence due to the inaccessibility of the location, the other groups couldn't access it.

This is a dangerous challenge which should be avoided as much as possible, especially in the case of pupils doing a math trails activity. This is because some of the kids can collapse out of fear or become traumatized. In the case of inaccessibility to a task location, students participating in a math trails activity would not be able to carry out the tasks.

In addition, math trails can be designed in such a way that, students can always call the teacher in times of need or in extreme situations call emergency services. Students should be informed when they need to contact the teacher directly and when to inform both the teacher and emergency services before the start of the math trail. Supervision of elementary school pupil by adults is crucial in math trail activity. This supports Davis and Hamilton (2018) suggestion that staff-student ratio is considered during such outdoor learning activities.

6.1.3 Understanding the tasks

Independent understanding of the tasks is another important factor that should be considered while designing a math trail activity. As suggested by Sharples et al (2009), the tasks created should be quick and have simple interactions. This is because the teacher or the designer of the trails is not always available or present with every group during the activity. Therefore, if some tasks are unclear it leaves the participants confused and not knowing what to do. This leaves the participants with no other option than to guess the answer. From the study, it was identified that unclear descriptions caused some challenges. For example, the imprecise nature of the answers made it difficult for the participants to figure out the units with which they were to answer the questions. Hence it left the participants with the option to guess the unit of the answer.

To enhance an understanding of the tasks, only the content that students have learnt and are familiar with should be assessed.

As expressed by one participant, his group did not understand the bicycle ramp task because the information was scanty which led the group not to understand the bicycle ramp task. This misunderstanding made the participant leave in the middle of the activity. Although most participants were happy that the math trails activity was good because the activity made students active while learning mathematics, this particular participant was not willing to do the math trails activity again.

When topics that students have no idea about are used, the tasks might look strange to the students. This leaves the students wondering about what to do, and how to solve the tasks which might eventually become boring. In the first case, the researcher intentionally included a task on trigonometry ratio which the students had not yet learnt about. The wheel-chair ramp task contained mathematical content that had not been taught to the students. Some of the students had an idea about how to do the wheel-chair ramp tasks whereas other students had no idea about which mathematical knowledge to use. Fortunately, the students were able to get the idea because the researcher was present with them at the moment, and realized the difficulty the students had in understanding the task. So the researcher explained to them the mathematical content needed to do the task. Some participants of the KKG math trails activity expressed how some words in the wheel-chair ramp task were difficult for them to understand. This is because they had never heard about “angle of elevation”.

With regards to the previous paragraph, math trails activities can be used to introduce a topic, however, it should be done meticulously. Students should be given the time to read about the topic on their own before doing this kind of math trails activity. Also, the students should notified this is an introduction to a lesson, hence they do a math trail prior to a new topic. This will may help foster the students conceptual understanding of what they yet to learn. Then, in this case, it is not strange to the students, because the students know they are yet to study the topic. But in the case whereby the students have no idea about the math trails activity being an introductory activity to a topic, the tasks become difficult to the students and they might eventually not see the immediate effect of the activity. This was the case for the wheelchair ramp task in the KKG math trails activity.

6.1.4 Time

Comparing the case of the KKG math trails activity to the case of the pre-service teacher's math trails activity, time was a challenge. For the case of the KKG math trails activity, the students couldn't complete the math trails activity because of time. The maths trail activity had to be completed within 90 minutes after which came another lesson. Therefore, students could not complete all the tasks. Especially when time was met with unfortunate rainy weather.

As mentioned earlier, the kind of instruments provided associated to the tasks can be time consuming. Comparing a 200meters measuring stick to a measuring tape, it is easier to use the measuring tape as compared to the measuring stick. The measuring stick involves lifting and rolling over, while the measuring tape only has to be pulled back and in. this means that the easier the tool to use, the less time consuming it takes during the math trail.

The students or participants in a math trail will need time to think about how to solve the tasks, do some actual measurements and move from one location to the other. This is one the main reason why the researcher agrees with Shoaf et al (2005) that the distances between the task locations should be shorter. Because the students would not have to spend much time walking from one location to the other.

Unlike the case of the KKG math trails activity, time was not a challenge in the case of the pre-service teachers' math trails activity. This was because the participants of the pre-service teachers' math trails activity had enough time to do the math trails activity as compared to the KKG math trails activity. Also comparing the participants of the KKG math trails activity with that of the pre-service teachers' math trails activity, the participants of the pre-service teachers' math trails activity had a stronger mathematics background which would not require them much time to figure out the what the tasks wants them to do and what mathematical knowledge to use.

It is possible for students to miss other lesson which follows right after a math trail activity. To avoid that, the student might have to stop the math trail and go for the other lesson. In the case where the distance between the location and school is far, it is possible for the students to miss a class right after math trail.

6.1.5 Weather challenge

Another major challenge that will prevent the running of a smooth math trails activity is the weather. The weather has a great impact when it comes to the decision of whether a math trails activity can be carried out or not. One of such weather condition is precipitation. Due to heavy rain, the math trail was postponed and done on a different day as opposed to our original plan for the pre-service teachers' math trails activity. A similar encounter was experienced by Hamilton (2018).The participants could have put on rain suits and boots, however, the fact that their books, phones and other accessories belonging to them could get wet should not be overlooked or undermined. As this can prevent the students from working or carrying out the tasks in the math trails activity. As mentioned by Williams and Scott (2019), the weather is one of the setbacks of outdoor math trails.

The issues about the weather should be given much attention because they can ruin an ongoing math trail activity. This was the case for the KKG math trails activity. The KKG math trails activity needed to be stopped for two major reasons. One of the reasons for ending the math trails activity with the KKG group was heavy rainfall (excerpts 5.8.2.1.2). The students' books and mobile phones were getting wet, and it was early in the morning. This means that, if they should get wet early in the morning, they would be wet throughout the day until their dresses dry up or they go home. No participant would like to have such kind of experience because of some mathematics activity. This can also take the interesting and fun part of the math trails activity away.

The weather can make a math trail a loss activity for students. If students might have to end a math trail activity because of harsh weather conditions, then the students would have nothing doing; except the teacher had a backup plan. Likewise, if a teacher had sought permission from another teacher for math trail and the weather turns to be bad a week before, it might be difficult to make amends. This can be challenging.

Some participants in both cases mentioned that the bad weather condition will be a challenge that will prevent a math trails activity from being run smoothly. However, some participants also

mentioned that, with the appropriate clothing and materials, the weather might not be that much of a challenge.

6.2 Benefits of math trails activities for students.

6.2.1 A math trails activity helps to improve the well-being of students.

One of the major benefits mentioned by all the groups interviewed was the joy and fun they had while learning mathematics outside the classroom. As mentioned by Mygind (2007) and Marchant (2019), one of the benefits of having outdoor activity was health and happiness. Also as expressed by most participants, math trails activity serves as a form of physical activity. This is because the students move around and get to stretch themselves and walk around as well.

I agree with Marchant et al. (2019) that outdoor learning improves the well-being of students. Students walking from one keeps the students healthy. The feeling of taking actual measurements and solving mathematical tasks alone put smiles on the students face. This makes the students feel like on they are on a field trip.

The feeling of happiness is connected to the entire math trail; the task description, understanding of the tasks, the students being able to walk from one location to another location, getting points for being able to answer correctly etc. collectively made the activity fun.

6.2.2 A math trails activity as a mediating tool

Math trails activity as an alternative for dressed-up tasks in the classroom can be used as a means of connecting what is learnt in the classroom to the real world. In this case, the students get the opportunity to picture more of what a distance of 500 meters would look like in a real measurement. Math trails activity can help the students to understand subjects like proportions, measurements etc. better. This is because the students get to estimate in their minds how big an area is while learning in the classroom because they have been measuring the area on an actual field. Math trail activity as a tool connecting classroom mathematics with the real world will help

the students understand better what the mathematical content they learn in books looks like in real life. This supports Cook (2010)'s claim that tools shape the way humans react with reality.

Through math trail, students can relate the mathematical concepts they learn to reality. Through math trail activity, a math concept like trigonometry ratio will not just be a classroom thing, but rather, as a subject related to the environment. This is so because, students may now be able to view wheelchair ramps as not just ramps but also having relation with the topics which the students thought were abstract. In the terms of mediation, math trail mediates students conceptual understanding and the reality.

Math trails activities will help the students to identify the forms of reasoning that arise in the context of learning in the real-world setting (Cobb and Bowers, 1999).

As expressed by the students how the math trails activity helped them get more understanding of the mathematics learnt in the classroom, it can be said in the terms used by Hasan (2005) that, math trail was a mediating tool, mediating between the students' classroom mathematics learnt and how it is applied in everyday lives. Compared to Kozulin (2003)'s psychological tools, math trails activity can be used as a psychological tool which helps learners to see the connections between mathematics and the real world. That is students will be able to estimate in their minds how things might turn out to be because the students have experimented it themselves.

In addition to the math trails activity being a mediating tool, the Actionbound app is also a mediating tool. In that, the GPS guide integrated into the app mediates the finding of the location. The GPS guide serves as a tool which guided the participants to the locations and tells the participants when they are going in the wrong direction. As you get closer to the destination, the GPS guide reduces the distance between you and the targeted location. Therefore, if the distance between you and the targeted location widens then it means the participant is going in the wrong direction. Also the pictures of locations which were put into the app mediated between the students and finding of the location. The picture gives confirmation to the GPS guide that you are at the right place. This helps make the participants feel reliable and that they are in the right place. This will help clear doubts, especially in the case where the buildings are similar.

The Actionbound app fits into the Robbins (2005)'s description of cultural tool. When designing a math trail, the culture of the people will determine what how finding the locations in a math trail

can be mediated. In a community with weak internet connection or no internet, the Actionbound software cannot be chosen the best mediator for finding the location. However, a map on a paper might be an option. To get the appropriate cultural tool for a particular community, you a teacher will have to find out how the community travels from one location to the other. For example, if a community uses intuition and number of distance walked to find locations, the teacher will have to employ such kind of tool to help the students find the task locations in a math trail. In the same way, if the use of mobile phones is common, then writing of the instructions and tasks should be given on a piece of paper.

6.2.3 A math trails activity promotes teamwork

Learning mathematics should not only focus on gaining knowledge in mathematics but also, on the social life of the students as well. Math trails help to draw students together as they collaborate with each other to solve tasks outside of the classroom. That is not to say that the socialization of students can be done only through math trails. However, math trails will help strengthen the spirit of teamwork. As mentioned in excerpt 6.4.2.5, each member in the group has a part to play in tasks to help achieve the group goal. This will also help the members of the group to know themselves better, that is by knowing what one person is good at doing. Students who are weak in certain areas of mathematics may seek for helps from group members through the group activity.

The above paragraph supports Fägerstam Grotherus (2018)'s findings that outdoor learning facilitates students cooperative learning. This is because, the students find themselves to be on a mission. Therefore, they unite to reach their goal. This fosters the cooperation between the students. As the students help each other to take measurements, make calculations together, search for ideas and solutions on how to reach the solution, it creates some bond and understanding between the students. Also, the teacher has to design the tasks in such a way that, it will foster cooperation and teamwork. Asabre (2013) in his article also emphasizes that math trail mobile learning collaboration among teamwork.

In both cases, the participants shared their experiences and thoughts on how the math trails activity.

6.2.4 Math trails as More Knowledgeable Other (MKO)

Another benefit of math trails activity is that it will help the students to gain more knowledge about the environment in which they study or live. For example, after solving the fire escape task, a student will have information on how long it is going to take for people to escape the building in case of an emergency. Another example is after solving the diversity tasks, the student's knowledge of diversity in the community will be broadened (Smagorinsky, 2018). From this perspective, the math trail is an MKO. The task information and the solutions to the tasks teaches the participants about the locations that are visited. This implies that, by the time the students leave a particular task location, they have gained some knowledge about that location. And that means math trail has taught them something new which makes the math trail an MKO.

As mentioned earlier by the participants in the math trails activity, the math trails activity helped them understand better some mathematical lessons done in the classroom. This makes math trails the MKO according to Smagorinsky, (2018). Also with reference to Abtahi et al. (2017), math trails activity is an MKO since the math trails activity guides students to understand what they are learning or have learnt better.

Math trails activities will help the students to become task creators and solve their own tasks. This is because as they explore the environment and learn through that, anytime they learn a topic related to math trails activity, they can explore the environment, create tasks and solve them on their own to help strengthen their conceptual knowledge. This have now gained some information, and can now relate the information to similar context.

The teacher also plays the role of MKO, however, the teacher is represented by the Actionbound. In this case, we can infer that the teacher indirectly plays the role of MKO through the design of tasks, task solution, information about the locations put in the Actionbound. In addition, the group members can also be a MKO. In the first, a student knew has to calculate trigonometry ratio, this student can explain how the calculation is done to the group member. This makes the student teaching the other a MKO.

6.2.5 The situated learning provides room for situated learning

The math trails activity provides its participants with the opportunity to learn in a real situation. The situation of classroom learning and solving word problems is different from the situation of doing math trails tasks. In the situation of math trails activity, the students do measurements themselves, discuss among group members and brainstorm to get the right mathematical models to use. This is different from the classroom tasks with measurements already provided. Students get to learn how difficult or easy it is to take measurements. In view of this, after a math trail activity, the student will be able picture how big the measurements in book is; on the ground.

The settings in the classroom are different from the settings of math trails activity. There is a lot space to work in the field (Cobb & Bowers, 1999). For math trails activity, you work on the ground, in real settings and not only in books with all the information provided for them. The air freshness is different from that of the classroom. The students gets to be relieved of the boredom of always learning in the classroom. For students who need practical lessons to understand a concept, math trail is a great activity for such students. Math trail may meet some learning needs of students.

As mentioned by O'Brien and Battista (2020) math trails activities will help students to conceptualize the math concepts they learn. When students partake in math trails activities, it helps them to create pictures of how the modelling will come out to be since they have had an experience with this in real life. This supports Billet (1996) that the math trails activity is goal-directed and students learn in an authentic situation in which they apply the math concepts learnt.

As students learn and do tasks in real contexts and situations, the students become socially relational as mentioned by Fox (1997). That is as students solve tasks, they begin to transfer the mathematical knowledge to social issues regarding the society. Students begin to try and relate the mathematical concepts they learn to the society they live in. This can lead to the students asking themselves, is it possible to use this math concept here or there?

6.3 Challenges faced by the teacher

6.3.1 Theory backing mobile learning activities

To help teachers and content creators of math trails to know the probable difficulties of having GPS-based maths trails, the teachers also share their difficulties faced as a planners.

One of the challenge a teacher can face while planning the math trails activity is finding an appropriate theory backing mobile learning. This is because such kind of theory does not exist as mentioned in Mehta (2016). Sharples et al (2016) postulate a theory for mobile learning, however, an explicit theory for mobile is not mentioned. This makes it quite difficult for teachers and researchers when planning and designing a math trails activity.

There are articles regarding mobile learning that a teacher can read to get idea on how to conduct mobile learning activities. Unlike theories like behavioral theory, constructionist theory etc. which can be stated and defined; mobile learning theories not have such statements and definition. O'Mailley et al. (2005) and Sharples et al (2005) have different meanings to mobile learning. According to O'Mailley et al. (2005) mobile learning involves the use of mobile phones and takes place outside the classroom; while Sharples et al (2005) suggested that mobile math trail can be mediated by technology. This can be challenging for a teacher to come into a conclusive definition for a mobile math learning. However, the underlying feature of mobile learning is that, the students move from one point to the other and outside of the classroom.

6.3.2 Technical difficulties

As expressed by the students who took part in the math trails that they had a hard time getting the points for finding the locations, the researcher also experienced a hard time finding the right spot for getting the points. The area of the circle into which the students needed to fall before they could get the points was fixed. That is there is a particular area to stand before getting the points. The KKG school is quite big and has about more than five entrances to the white building. This made it very challenging to put the circle at the center which all the groups would pass. However, the problem was such that there was nothing the researcher could do about it. This is because, the math trail activity was designed in such a way that, as the students are a few meters away from the precise location, they get the points. Hence, the difficulty faced.

Also, the Actionbound app did not have the feature which could let the designer of bound to input decimal figures. Due to this, every decimal answer needed to be rounded the user inputs the answer. Therefore, if a math trail designer needs to involve decimals in the answers, the inability of the app to allow decimal figures becomes a shortcoming.

The above technical challenges were not mentioned by Buchholtz (2017), Gurjanow and Ludwig (2017) and Ludwig and Jesberg. However, this is the case for only Actionbound app used for the study. If a teacher want to teach rounding up of figures through math trail, then the Actionbound is perfect for that. However, if the desired learning outcome includes approximations, then other software supporting decimals can be used.

6.3.3 The relationship between the area chosen for the activity and the mathematical content to be learnt.

As mentioned by Edward-Jones et al. (2018) finding out which activities are suitable for outdoor learning was experienced. This was a difficulty I faced by as a teacher while discovering the mathematical contents relevant to students' learning. During the designing of the tasks for this first case, statistics was one of the topics which was difficult to use for mobile math trails. Linear graph tasks were difficult to design. This was because after designing the tasks, the graphs were curves but not lines. That is after designing a tasks with the aim of getting a linear graph; and the graph turning out to be something different can be challenging for the teacher. The teacher may have to ignore this task location, since that location do not support the desired learning outcome. By the time the teacher comes to realization, the distance between the task locations are wide. Distances which will require the participants to walk a lot without any math tasks should be avoided as much as possible, as suggested by Buchholtz (2017) characteristic of math trails. This is because the longer the distance students have to move from one location to the other, the more distracted the students might get. And the teacher will have to get a lot time for such kind of a math trail.

The above chapter implies how challenging it is to the teacher in deciding which mathematics suits for only classroom activities; and what mathematics can be included in a math trail. Based on this I am of the view that, not all topics can be included in a math trail.

6.3.4 Information in task description

One of the challenges faced as a task developer for the math trails activity was the amount of information to put into the task. The tasks characteristics suggested by Sharples et al. (2009) that 'interactions should be quick and simple made it difficult to decide the amount of information that should be provided in the task. This challenging because the amount of information provided in the task has an impact on the students' understanding of what to do. This is because, the teacher

will have to decide what is enough information and what is not enough for the students. Much effort should be put in the preparation of the tasks for math trail; most importantly because of the factor that, the teacher is not with each group during the math trail.

In cases where students are not able to understand the tasks, it leaves the students with frustrations. This will not help both the teacher and students in actualizing the goals of the math trail activity.

Cultural-specific tools such as Actionbound made it a little challenging. This is because unlike using a GPS-based app, Shoaf et al. (2005) had enough space to write because they did not use any mobile application. In an mobile app chosen for math trail, there can be little space to provide information and to explain tasks. If the information that is being put in a chosen app is not enough, it can lead to students not understanding what the teacher wants them to do. This can lead to a math trails activity being boring because the participants of the trails could not understand the task. This challenge connect to the technical challenge (that is screen) mentioned by Mehdipou and Zerehkafi (2013). Unlike provision of tasks on paper, the text in the Actionbound app were not big. The more the information provided, together with smaller text, it can somehow be boring for the students. This can lead to an undesired outcome like students missing out information.

In choosing culture specific tools like mobile apps, the teacher should be well trained or well informed of the affordance and constraints of using the app. If a teacher does not know well the features of an app works, the teacher would not be able to make very good use of the software to the benefit of the students. This can pose challenges for both the teachers and students.

6.3.5 teacher and student relationship

In cases where math trail are to be adopted by a teacher, the content of the math trail should be well checked. This is because the developer of a math trails might think generally for it participants. However, the teacher knowing the level of his students will know the right levels and tasks to use. As a teacher, I designed the tasks for a math trail without establishing any relationship with the students to know their strengths and weakness in mathematics. I also had no idea of how the students reacted in cases of not understanding the tasks.

This is important because, in cases of difficulties and frustrations, the designer of an adopted math trail might not be present to clear doubts and give clarification to tasks. This can be worse if the teacher who adopted the tasks does not understand every detail provided in the task.

In addition, during a math trail, the teacher is not present with all the students as it was in the classroom. A student cannot raise a hand or just call a teacher for help during a math trail activity. The settings of math trails are different from that of classroom settings. Due to this, it will be difficult for the teacher to relate with the students in the way as done in the classroom. In situations where other supervisors are chosen to help,

6.4 Researcher's benefits

6.4.1 Teacher gains more experience in how to connect mathematics with reality.

While designing the math trails tasks, the experience in designing the math trails activity opened my eyesight as a teacher, to know how to relate the mathematics content with the real world. Especially during teaching, you can give more examples related to the real world to help foster students' understanding of the topics the teacher is teaching.

Teachers gain more experience while designing a math trail activity. Through math trail, a teacher would not need to always rely on textbook to give examples and assignments in class. However, the teacher's experience of designing tasks connected to reality will help the teacher to give comprehensible teaching of concepts to the students. In situations where students have difficulty understanding some math concepts, the may be able to connect the mathematics to the reality to help the students understand well.

Math trails can be used as an alternative for classroom teaching. Aside from word problems which are given to students as a way of helping them relate the mathematics learnt with the real world, math trails activity can be also used. With math trails, the students get their hands on real objects. Also, in exchange for classroom tasks, math trails activity tasks can be assigned to students, and then discuss the tasks as a group, and also look at how other groups solved their work.

6.4.2 Teacher gains knowledge about the society

Just as mentioned previously that math trail helps the students to know more about the community they live in, so does the teacher benefit. It helps the teacher to know more about the environment, such as the safety precautions in the environment, the average number of people dying per year in your community etc. As stated by Sharples et al (2005), one of the goals of mobile learning is to offer both formal and informal learning. This learning happens implicitly as the main idea behind the tasks is not to know the society or environment around the students. However, as a teacher

explores the community while designing mathematical tasks, the teacher become equipped with knowledge about their community.

6.4.3Math trail as a method of teaching.

Math trail can be chosen as a method of teaching or assessing what has been taught in class. For a teacher to asses the conceptual understanding of his students, math trail can be a tool for assessment. This is because, math trail connects the classroom learning with the real contexts. Therefore, how well students perform will be able to tell the teacher the extent to which the students have understood a concept.

Also, students learn differently. To cater for the need of students who learn through practice, math trail activity can help cater for such student needs. A teacher may not directly know the learning needs of all his students. However, such kind of activities can help cater for some student learning needs which the teacher may not have been aware of.

6.4.4 Math trail can give opportunities to explore

As a researcher, it helped to know the existence of learning apps with GPS already installed and how to use them. When planning the activity, how to find the task's location was a hurdle until I was introduced to several learning apps.

In this technological age, where people rely a lot on technology is a great opportunity for the teacher to exploit these technologies to the benefit of the students. The teacher, should search for apps with the best features for supporting math trail activities. This will help the teacher to catch up with the existing technology for the benefits of students.

CHAPTER 7

Conclusion

7.1 Summary

This study was a multiple case study aiming to find benefits and challenges of carrying out math trails activities with a GPS-based app. There were two cases studied, both based on organizing a math trails activity with several tasks connected to locations in the school environment, and thereafter interviewing participants. The participants of the first case were students at Kristiansand Katedralskole Gimle (KKG), hence the name of the first case was the 'KKG math trail'. The second case was done with pre-service teachers in their 4th year from the University of Agder and hence the name of the second case was the 'pre-service teachers' math trail'.

Before I carried out the two cases, I organized a pilot study, which was a math trail without the use of a GPS-based app. The first case, the KKG math trail, built on the discussion and conclusions that I drew from the pilot study. The second case, the pre-service teachers' math trail, built on the discussion and conclusions from the first case. So, the second case study was done with improved versions of the instruments used for the first data collection regarding both math. trail and the interview guide. This research design shows that the study was design-based research.

The GPS-based mobile app Actionbound was used to help the students find the locations, it also contained the series of tasks for the math trails and to answers the tasks. All participants in both cases expressed that the GPS-based app helped to make the math trails activity fun by doing the activities in the form of a game.

In both cases, interviews were conducted after the math trail activity to find the benefits and challenges that the students encountered while doing the math trail activity. The pre-service teachers played student-teacher role in this multiple case study. The interviewer audio-recorded voices of the students and the recordings were deleted after the transcriptions. The interviews of the first case was done physically while the second case's interview was conducted virtually.

Discussion of the results was done based on the data from the KKG math trails activity, the UiA pre-service teachers' math trails and the researcher's experience of doing and planning the math trails activities. The discussion was done based on individual experiences from the math trails activity. Some of the findings were experienced by all the participants who participated while some of the experiences were not experienced by all. Recommendations made by the participants during the interview were not discussed, however, they will be mentioned in the recommendation section below.

One of the major benefits of having a math trails activity was its relation of mathematics content with real-world tasks. The major challenge faced was accessibility to some of the tasks' locations.

Since there were some limitations (see paragraph 8.4 below), the results of this study cannot be generalized but rather lead to suggestions and tentative conclusions.

7.2 Addressing the research questions

The research questions that the study sought to answer were

1. What are challenges students face when doing a GPS-based math trail?
2. How do GPS-based math trails activities benefit students?
3. What are possible challenges teachers face when planning and implementing GPS-based math trails activities?
4. What are benefits teachers derive when planning and implementing GPS-based math trails activities?

The purpose of the first and second research questions was to identify the challenges and benefits that the students derived while doing the GPS-based math trails. Also, the challenges teachers encountered and the benefits the teachers derived while planning the math trail activity were discussed. The reason for doing this is to help teachers and planners of math trail activities to know the benefits of math trails to students, and also, to know the possible difficulties that will prevent math trails activity from being run smoothly as well as to find possible solutions that will help in planning a smooth math trails activity.

The tasks which were used for the math trails activities for both the first and second case studies are written below. The location chosen for the first case was quite different from that second case. The task locations for the pilot study were different from the first and second data collection. The tasks for the first case at the KKG did not include the diversity and fire escape tasks. The tasks for the second case at UiA did not include the bicycle playground tasks.

This is the final chapter of the study. This chapter presents the summary of the entire research, limitations to the study, implications for teaching, and suggestions for further research.

7.3 Answering the research questions

Based on the analysis done in relation to the literature review, the conclusions drawn from the math trails activity study done with the university students are mentioned below.

In conclusion, the challenges that were faced by the students were;

- Getting the points for finding the location
- Insufficient understanding of tasks due to insufficient information in the task description
- Accessibility of task location
- Time
- Weather conditions

The benefits that students derive from math trails activities were

- Math trails helps to improve the well-being of pupils and students
- Math trails activities serve as a mediator for connecting classroom mathematics with the real world
- Math trails activities promote teamwork among students
- It equips students with knowledge about the environment they live in
- It helps students become task creators

The challenges faced by the teachers while designing and doing the math trails activity were

- Finding an appropriate theory backing mobile learning
- Technical difficulties involving the use of the app chosen for the math trails activity
- Getting the desired mathematical content to be explored from the chosen location
- The difficulty concerning the amount of information that should go into the tasks.

The benefits derived by the teachers while planning the math trails activity are

- It helps teachers or researchers to become to task creators
- Math trails can be used as an alternative for classroom teaching and learning
- It helps the teacher to know more about the community
- It helps the teacher to know the technologies available for teaching and learning mathematics.

7.4 Limitations of the study

Several limitations to this study are mentioned below.

As mentioned earlier, the findings of this study cannot be generalized. In the first place, both data collections were with only one group, and not with different classes at KKG or different pre-service teacher groups at UiA. At each of the institutions, I only found one teacher with a course taught in English. A second limitation is that the findings are subjective to the researcher and the students' experiences. Some of the challenges were experienced by some students while some did not experience that challenge at all. In the same way, the researcher's difficulties faced during the study was encountered by only the researcher and based on the researcher's subjective experiences. Therefore, the results cannot be generalized but rather can be used as a suggestion.

In addition, the results of this study cannot be generalized because not all the views from the participants were captured. This is because not every participant of the math trails activity was interviewed. Also, the number of participants used for the study is not enough to be able to

generalize the conclusion of this study. 28 participants in total including the researcher participated in the main data collections.

Also, not many math concepts were used in the math trails tasks. Therefore, it cannot be generalized that every math concept will be appropriate for math trails activity tasks. As mentioned earlier in the study, a tasks about linear graphs could not be given because of the nature of the tasks.

7.5 Recommendation for implementation in schools

Based on the results and conclusions drawn from the study, I would like to make some recommendations if this a GPS-based math trails activity is to be implemented in a school. The section is not only based on the teachers'(including the pre-service teacher and lecturer) views but also includes recommendations from the students.

The app was one that rewarded points to the participants for finding locations and for giving the correct answers. This functionality can be eliminated from math trails activities. Especially in the case where the points are interfering with the participants finding the task locations. Also, if a teacher wants to avoid competition among students and focus only on the mathematical activities, it is advisable to eliminate the points for getting the right answer from the app.

Also, I would like to recommend that task descriptions should be well piloted before these are given to the students. The description should be clear and simple to be understood, especially in the case of elementary pupils. Buchholtz (2017) and Shoaf et al. (2005) give tasks descriptions that can be used as a guide when creating the task content. Also unambiguous descriptions of the task locations should be given. I would recommend that a teachers add a picture to the description of a location if possible.

In order to be rest assured of the safety of the participants, a trail designer should experiment the task locations to ensure safety issues. Also it is to be ensured that locations chosen for the math trail activity are safe and accessible.

In the case where the app for the math trail tasks checks the answers and offers immediate feedback, it should be checked that accurate details are provided in the answers. The unit of an answer should be made clear to the students. Also, it is advised to make clear whether decimal

figures are supposed to be rounded before choosing an answer. A teacher should not assume that the students know what the unit of the answer is or when they should round the figure.

In the present study, I organized math trail activities in the immediate environment of the school/university. However, students can also have educational trips to places further away, like for example factories where one could also do a math trail activity to strengthen students' conceptual understanding of some topics learnt.

This study is not ruling out that classroom mathematics and word problems given to students in class are not the best. However, this study tries to suggest other ways to make students see the usefulness of mathematics in reality. Although a math trail activity can be fun and can make students realize the role of mathematics in real-life, it shouldn't be used that often. This kind of activity can be done to introduce a topic or assess students conceptual understanding of what has been learnt in class. This needs careful planning. The difficulties and challenges mentioned in this study can be used as a guide to reduce the possible challenges that may be encountered.

7.6 Recommendations for future studies

If research on the difficulties and challenges of having a math trails activity is to be done, I would like to recommend the following ideas.

Include other mathematical concepts other the ones used in this study. Is it possible to include topics like regression, limits, graphs and pie charts etc.? If these kinds of topics can be included, was is difficult finding locations for such kind of topics?

Also, include more participants, and participants from different levels of schooling can be invited to participate. For example, elementary pupils can be included, as well as students with different educational background to find out their views on math trails activities. Designers of math trails activities like Buchholtz (2017) and Gurjanow and Ludwig (2017) could be interviewed to share their views on the challenges and difficulties they encountered while designing math trails activities.

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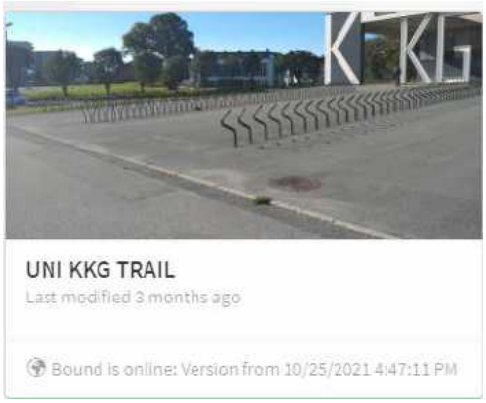
APPENDICES

Appendix 1 Actionbound

a. Picture of Actionbound app

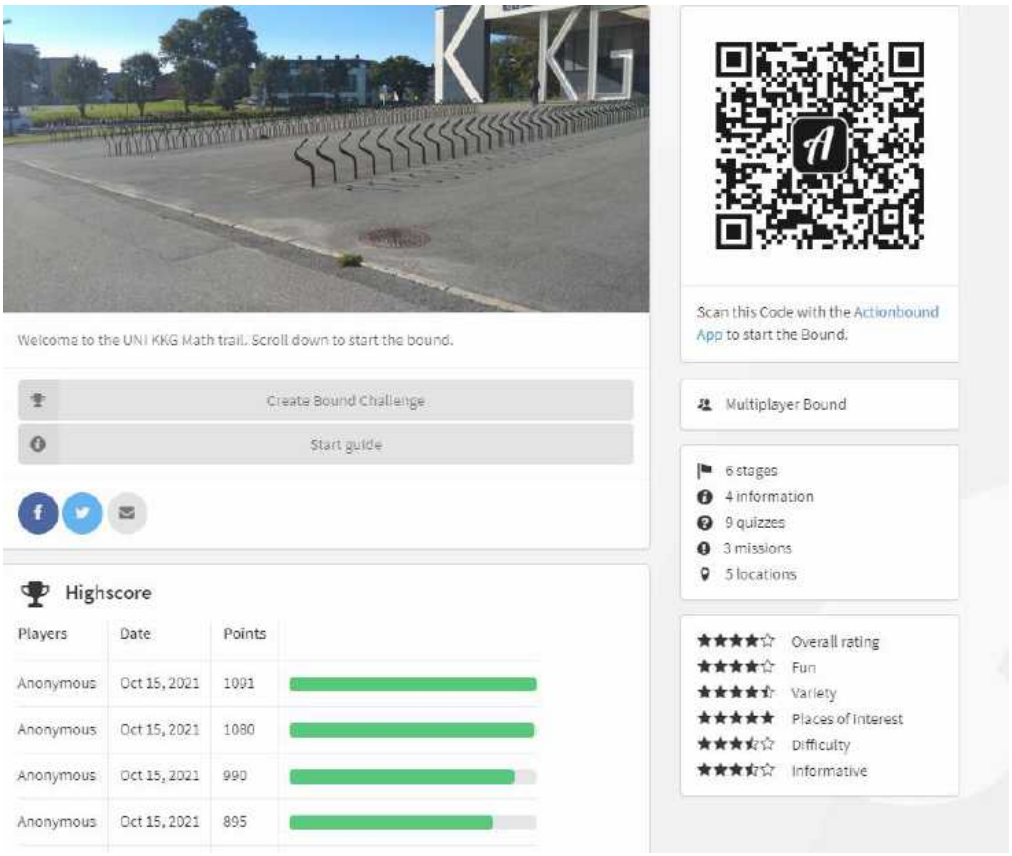
b. The bound used for the KKG math trail

c. The bound used for the pre-service teacher's math trail

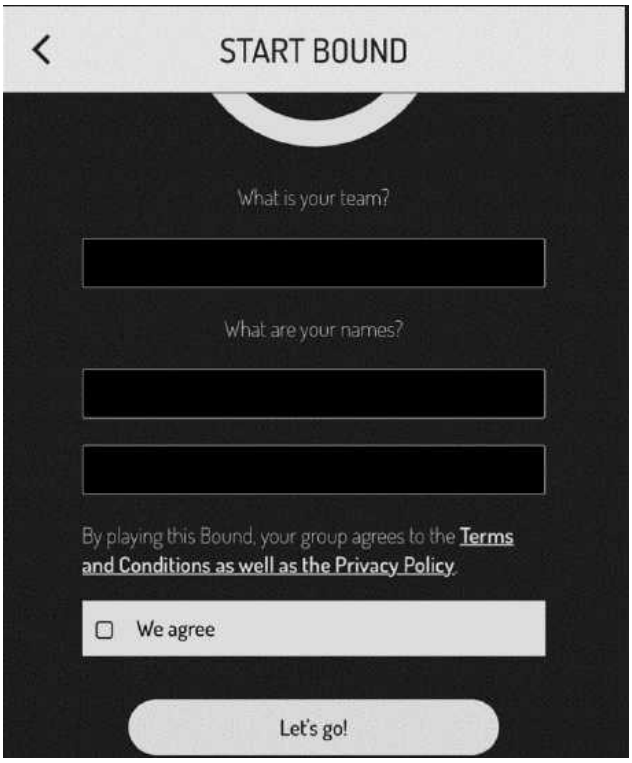


d. The scan code needed to scan before students can begin a bound

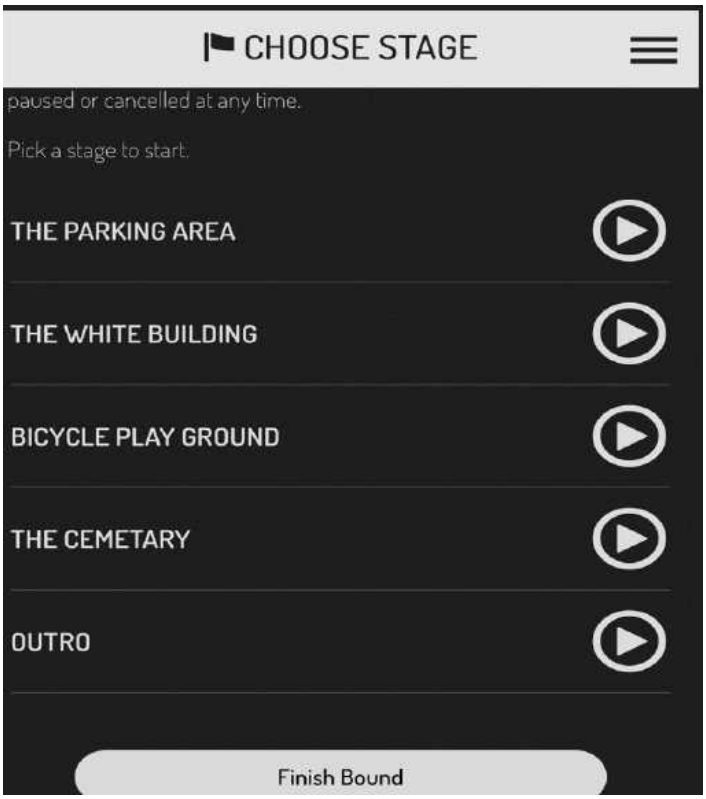
e. The first page the participants see after scanning the code



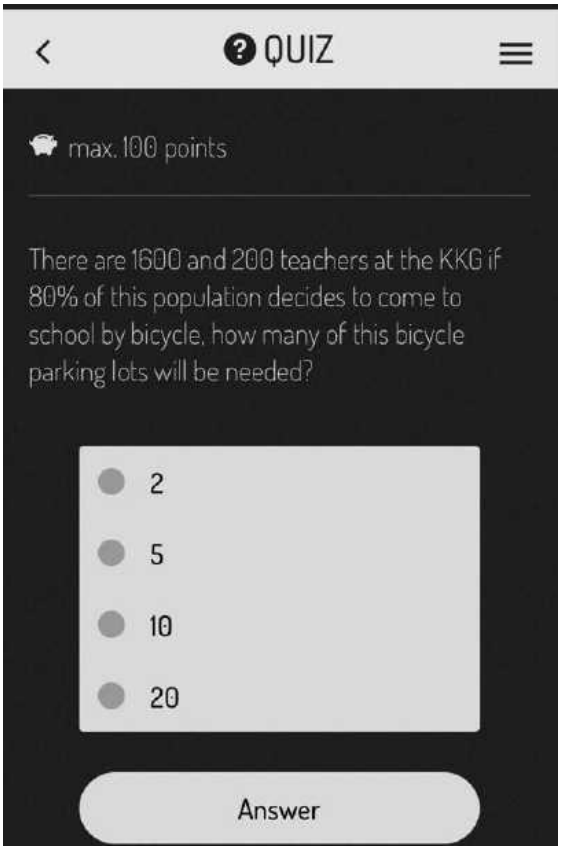
f. Space to provide information about the participants



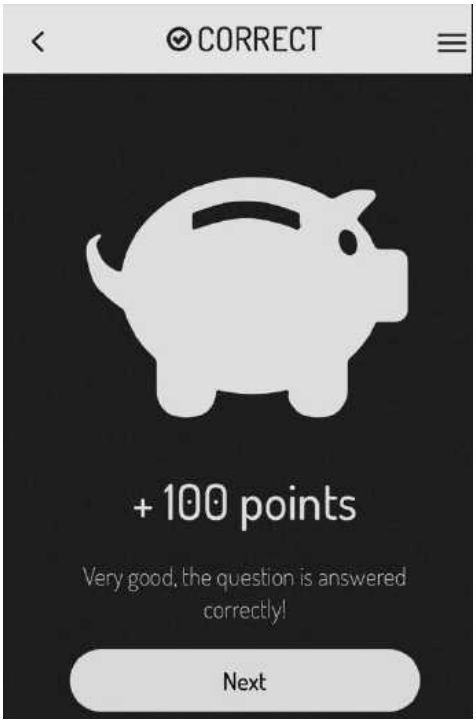
g. The stages to played and the pressing of the finish bound to end the bound.



h. How the tasks together with their answers look like in the app



i. A questioned answered correctly in the Actionbound app



j. A question not answered correctly in the Actionbound app


NOPE
1188
was the wrong answer, sorry. The correct answer is:
1800
Next

Appendix 2
Information letter

Are you interested in taking part in the research project

"STUDENTS MATHEMATISATION THROUGH MATH TRAIL: ITS BENEFITS AND CHALLENGES".

This is an inquiry about participation in a research project where the main purpose is to investigate the benefits and challenges of math trail. A mathematical trail is an activity in which a location is given to students where they are to carry out mathematical tasks to help solve some problems using mathematical models. Students engage themselves in the activity and try to come out with solutions to the problem at hand. In this letter, we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project

The purpose of the research project is to investigate "the challenges and benefits of a math trail". The research study tends to address this main question;

What are the benefits and challenges of carrying out an authentic task through math trail?

The research project forms part of the master's thesis undertaken at the University of Agder.

Who is responsible for the research project?

The University of Agder (Mathematical Sciences Department) is the institution responsible for the project. The researcher responsible is Jennifer Ntim (Master student) and the project is however supervised by Professor Pauline Vos

Why are you being asked to participate?

You have been selected because you are in the upper secondary school and have learned algebra, area of solid figures, estimations, etc. On the other hand, permission has been sought from the teacher responsible for mathematics.

What does participation involve for you?

The methods which will be employed for data collection are handwritten materials and interview. The handwritten materials are mainly about the answer sheets provided by the students whilst the interviews will be tape-recorded.

- If you chose to take part in the project, you will have a walk around the school and the Oddernes cemetery where the activities would be carried out.

- You will also participate in a 10-20 minutes interview, where you talk about how the math walk went and how you solved the tasks and your views about the entire activity. A voice recorder will be used during the interview.

- I will also ask your teacher to provide information about the mathematics courses you have taken and the teaching activities organised by the teacher.

Participation is voluntary

Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw. It will not affect your relationship with your school or teacher. No information or data will be recorded on students who do not participate in the research, especially during the mathematics lessons observation.

Your personal privacy – how we will store and use your personal data

We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

- The only persons that can have access to the personal data are the researcher, supervisor and the censor at the University of Agder.

- All necessary precautions will be taken to ensure that no unauthorized persons are able to access the personal data. I will use pseudonym to ensure your identity is not revealed in any part of the research project. The personal data will be stored on an external hard drive and the University of Agder server.

The participants will not be recognizable in any form of publications.

What will happen to your personal data at the end of the research project?

The project is scheduled to end on the 30th of May 2021. The personal data including the voice recordings will be completely deleted within a period of six months after the research project is done that is 30th of October 2021.

Your rights

So long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?

We will process your personal data based on your consent.

Based on an agreement with the University of Agder (Mathematical Sciences Department), NSD – The Norwegian Centre for Research Data has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?

If you have questions about the project or want to exercise your rights, contact:

- The University of Agder (Department of Mathematical Sciences) via

o Pauline Vos (Supervisor), by email: pauline.vos@uia.no

o Jennifer Ntim (student), by email: jennifern@student.uia.no or by telephone: +47 96711479.

- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

Consent form

I have received and understood information about the project 'mathematisation through math trail: its challenges and benefits' and have been given the opportunity to ask questions. I give consent:

- to participate in the group activities
- to participate in an interview
- for notes to be taken about my involvement during the activity
- for my teacher to give information about me concerning the mathematics courses I have taken and the teaching activities in class to this project

I give consent for my personal data to be processed until the end date of the project, approximately October 2020.

(Signed by participant, date. NB! If you are under 16 years old, your parent/guardian also needs to sign)

a. NSD approval

Notification form /

Mathematisation through math trail: it benefits and Challenges /

Assessment

Reference number

679577

Assessment type

Standard

Date

16.08.2021

Project title

Mathematisation through math trail: it benefits and Challenges

Data controller (institution responsible for the project)

Universitetet i Agder / Fakultet for teknologi og realfag / Institutt for matematiske fag

Project leader

Pauline Vos

Student

Jennnifer Ntim

Project period

01.10.2020

-

30.11.2022

Categories of personal data

General

Legal basis

Consent (General Data Protection Regulation art. 6 nr. 1 a)

The processing of personal data is lawful, so long as it is carried out as stated in the notification form. The legal basis is valid until30.11.2022.

Notification Form

Comment

NSD has assessed the change registered on 21.07.2021.

We find that the processing of personal data in this project will comply with data protection legislation, so long as it is carried out inaccordance with what is documented in the Notification Form and attachments, dated 16.08.2021. We remind you to update theinformation letter with the correct end date of the project (2022 in stead of 2021).

Everything is in place for the processing to continue.

FOLLOW-UP OF THE PROJECT

NSD will follow-up the project at the planned end date in order to determine whether the processing of personal data has beenconcluded.

Contact person at NSD: Hildur Thorarensen

Good luck with the project!

Assessment of processing of personal data

Appendix 3 (Piloting)

Tasks

SWING SAFETY

THE TASK: Swings are children's favorite places in playgrounds. Many young children, teenagers, even adults enjoy using swings. Even though swings are enjoyable, they are also places where many accidents happen. Many children are brought to emergency rooms in hospitals due to accidents at swings*. The accidents may be due to falling off the swings for pushing too hard and flipping over, being hit by a swinging child, or arm dislocation while pulling a child at a swing.

To avoid being hit by a swinging person, it may be helpful to place lines on the ground beyond which other persons should not walk through, while someone is using the swing. To illustrate such a safety line, see the figure on the left above. Where should these lines be drawn? Help the playground designers develop a guideline for this. What do you need to consider for such guidelines?

https://www.calbomschwab.com/personal-injury-news/dangers-swing-sets-head-injuries-children/

IDEAS FOR SOLUTION: You may want to consider the height of the swinging poles or the length of the swings.

(source: https://www.pinterest.dk/pin/312718767848987330/)

What is the maximum angle a typical swing can be swung? How is the danger zone" related to the length of a swing? How is it related to height of the swinging poles? Which one would be better to use?

Site seeing is a lovely thing that most people love to do for relaxation. This is a fountain very close to the Kristiansand Cathedral in the city centre of Kristiansand. As usual, people are seated around beholding the beauty of the fountain as they relax in the chair. People especially kids love to play in the water, however with time if the water is not changed. It becomes slimy with time and needs to be changed. For a fountain worker who has to flash out the water and put another fresh water into it, he might be thinking of how much water to put in the tank to fill the basin to a particular level which will not overflow the fountain, how do you think this worker can refill the tank constantly without having to think adjusting the water and thinking whether the tank in the will overflow the circular basin.

Tasks:

1. Identify the geometric shapes in this structure.
2. Assuming that the bottom of the fountain is level with the ground, estimate the depth of the pool and then estimate the number of gallons of water that the fountain can hold.
3. Estimate the circumference or perimeter of the circle.

Ideas for solution:

You may have to find or consider measuring the diameter of the circular surface, the depth of the the water in the basin, and the volume of circular base.

Interview guide

1. What group are you representing?
2. Was it difficult finding access to the place? What are your reasons for your answer?
3. Was it difficult trying to understand the task? What are your reasons for the answer?
4. Was it difficult finding the mathematical idea behind the task?
5. Did you need any special material which you did not have at hand and made your work difficult?
6. Were the tasks boring?
7. Did you realize that mathematics is around us everywhere in the community?
8. Do you think mathematics is important and needs to be appreciated and learnt even if it's difficult at certain times?
9. Was the math trail activity helpful to you as a student? What are some of the benefits you had through the math trail?
10. Have you ever thought that mathematics is not important?
11. Do you think that if math trail activity is added to class activities it will help take the idea that math is not important away? Why do you think so?
12. What are some of the challenges you faced when carrying the activities?
13. What can you say about math trails?
14. What do you think should be added to this activity to make it more beneficial to students?

15. What are some of the difficulties you saw the students faced while carrying out the activity?

16. From your point of you, do you think this task is beneficial to students? How are they beneficial to the student?

Transcript

Transcript of interview

I: Was it difficult finding the place that I gave you to go both at the beach and at the city centre?

S: No

C: Not at all

I: Why?

C: its familiar

S: we are living here for nearly one-year now

I: So it's a familiar place you know.

B: yeah

I: And coming to the activity itself, the work itself was it difficult understanding it?

C: Mmmm no

I: Okay, say is the no both for the swing task and the fountain task since there were two tasks involved.

C: no

S: for the swing matter I think it was somewhat difficult to understand what you want from the task and to understand what the safety zone whether the safety concerns the one sitting on the swing or the person passing by.

I: And what about you Chandrika?

C: mmm the first time it was confusing actually (referring to the swing activity) but later on I understood

I: So did you realize later on that the safety was concerning the person standing somewhere or standing on the swing. Which of them to be precise

S: later I understood what you expect from the problem.

I: So if the researcher which is myself had not gone with you myself would you have been able to carry out the task? Supposing I had given you the work for you to go the place alone and do the work will you have been able to do?

C: ahh. I don't think so

I: Okay

S: the fountain matter is easy it's okay

C: yeah it's easy (referring to the fountain task)

I: Was it difficult finding the mathematical idea behind the task?

C: that is a basic mathematics, it took time to remind

S: we could take the mathematical idea but we couldn't remember the mathematical formulas to use.

I: So you had an idea about what to do but as to the particular formula to use you couldn't remember.

S: yes

I: And were the tasks boring

B: no!

C: it is fun (laughs after saying that)

I: So you had a little fun and a little challenge solving the task

S: yes

I: Did you realize while doing the task that the mathematics that we do is around us?

C: yeah! A lot

S: yeah

C: yeah that is the final message I got. Even though we don't think like, that, everywhere we can see the mathematics.

I: Do you think mathematics is important?

B: yeah

S: exactly

I: Why do you think it is important?

S: because in everyday life, mathematics is everywhere

I: although mathematics is important, did you realize through the task did you find out or get to know that but maybe by doing this task I got to know that it is more important and more around us?

S: ehmm, yes

C: thinking about the fountain case, I think back, if there is no formula, you have to be guessing how many gallons and just count until you are done filling. It is easier done if you apply mathematics and get the number of gallons needed at the time.

I: Do you think this math trail is a good activity for students?

C: yeah, because I learnt that as a teacher in a school, student who face many problems in mathematics, if the mathematical task they do is the same as your task, if it is practical, funny, they don't get bored about mathematics, they will learn a lot and they will be happy.

I: And what do you also think S? is it good that students go out for such activity?

S: yeah. Because you can understand what is actually the idea behind this theory.

I: So what are some of the benefits that both of you had doing the math trail? Did you get anything beneficial from doing the activity?

S: yeah, actually from the activity, got the idea that we have to be more careful about people who are on swings and those passing by the swings and that the safety zone concept we got that.

I: And what are some of the challenges that you faced when carrying out the task?

S: to measure the exact distances

I: Was it the guessing using your height or by sight

S: yes yes

Okay

So in general, what can you say about the math trail activity that we did?

S: very good so that we can get some idea about the fountain matter if someone is to do that work or something similar and about the safety matter.

C: it is a good activity not bad but, I mean it's just two activities for two concepts but we can expand. You are so specified. It's just a tiny area because mathematics is so vast. I would like it if there are more variations and alternatives to prove your concept, it will be better. I prefer more alternatives. Then I can choose from the area I like best.

Appendix 4 KKG math trail

Tasks

1. There are 1600 students and 200 teachers at the KKG. If 80% of this population decides to come to school by bicycle, how many of these bicycle parking lots will be needed?

2. Do you see the rectangular field from entrance 3.1 to 3.4? How big is this portion in meter square?

3. Find the white building behind the KKG with some volleyball pitch behind it.

a. building regulation demands that the slope of a wheelchair is not steeper than 1:12. Is the wheelchair ramp the white building designed to suit this regulation?

b. What is the slope of the ramp in percentage?

4. do you see trees in front of the building of approximately the same height? Estimate the height of this tree.

5. Do you see the curves which the bicycle passes on? this is a part of a circle. How big is this circle in the meter square?

6. This is the Oddernes cemetery closer to the UIA bus stop. How wide is the space from the line on the last burial to where the yellow signboard?

a. How many graves can fit into this yard?

b. From 2017 to 2019, 387 graves have been buried in the new oddernes cemetery. how many years will it take for this yard to full?

b. Interview guide

Interview Guide

This interview is being done as part of the data collection for Jennifer Ntim's master thesis; ''Students Mathematization through math trail: its benefits and challenges''. You are taking part in this interview because you participated in the math trail activity. I would plead with you to give honest answers as much as possible and anonymity of this information is secured. You can hold me responsible if your voice is being played anywhere or your data is used for any other purpose apart from the purpose of carrying out this research.

You can have your tasks with you for reflection of what happened during the activity.

This interview consists of three parts. The first part is about the challenges you faced, the second part is about the benefits you derived, and the third part is about your opinion on what could have been done to make the activity much better.

1. What group are you representing?

Challenges

2. Was it difficult finding access to the place? What are your reasons for your answer?

3. Was it difficult trying to understand the task? What are your reasons for the answer?

4. Was it difficult finding the mathematical idea behind the task?

5. Did you need any special material which you did not have at hand and made your work difficult?

6. Were the tasks boring?

Benefits

7. Did you realize that mathematics is around us everywhere in the community?

8. Do you think mathematics is important and needs to be appreciated and learnt even if it's difficult at certain times?

9. Was the math trail activity helpful to you as a student? What are some of the benefits you had through the math trail?

10. Have you ever thought that mathematics is not important?

11. Do you think that if math trail activity is added to class activities it will help take the idea that math is not important away? Why do you think so?

12. What are some of the challenges you faced when carrying the activities?

13. What can you say about math trails?

14. What do you think should be added to this activity to make it more beneficial to students?

15. What are some of the difficulties you saw the students faced while carrying out the activity?

16. From your point of you, do you think this task is beneficial to students? How are they beneficial to the student?

c. Transcription of interview

GROUP ONE (G1)

I: was it difficult finding access to the place?

R1: I didn't find it that difficult to find the areas. Although Actionbounbd had a tracker on the phone, I wasn't kind of able to locate the place although we were at the right place. but we got to do the tasks anyway.

I: was it difficult trying to understand the tasks?

R1: some of the tasks had words that we weren't familiar with.

I: which kind of words?

R1: I don't remember the exact words but I think it was the tasks at the white building, like angle of elevation, we have never heard of it before. That was hard but other than that I guess, we saw another tasks which we couldn't really understand but the question was to round up the answer we didn't know so we lost some points there.

I: the materials that I provided you with, you had your own calculators, a note pad to write in .and a measuring stick. Were they relevant for the task?

R1: yeah, it was useful, but the measuring stick was short.

I: and did that give you any problem?

R1: I'm not sure, to be honest. So we just measured our step with the stick and measured the dimensions with our steps.

I: did you see the weather as a challenge?

R1: it was cold, but it didn't hinder our ability to do calculation but since we had to travel around that was a bit difficult. I would probably be able to do the tasks even if it rained. But if the rains are heavy and snowing heavily with a windy weather then it will be very challenging.

I: so do you think if you had enough time you would have completed the tasks?

R1: yeah. I think we had one area left to go to if not for time sake and the rains.

I: was it difficult trying to find the locations you were supposed to go to?

I: so did you get any points for getting to the points?

R2: no. we still got hundred points for getting the right answer but not for the locations.

I: was it difficult understanding the tasks?

R2: no. it's just that, our team kind of acted on impulse, "okay let's do this" but we should have just stopped for a minute and actually read the question properly and then we should have

proceeded. We ended spending a lot of time on one question because we didn't read it properly in the first time.

I: were the materials provided enough?

R2: yeah. Honestly, the best that could have been provided to us because, it was really connected to the tasks and also connected with teamwork and I think the number of people in the group was good and having two measuring sticks made it easier for us to carry out easier instead of using one, it made our work more effective and efficient. And being able to notice some things down on a notepad was great because if we want remember something then we can quickly go back to it.

I: probably because it rained and you couldn't complete the task but do think if you had more time you would have been able to complete the tasks?

R2: oh definitely. But we had to come back early because it started raining very bad and the books were getting wet and the phones were getting a little wet but I think if the weather wasn't that bad we could have completed all the exercises.

I: what are some of the benefits that you got from the activity?

R2: like again it helped to understand like the value of math and why it is important we focus so much on it because math is all around us. Like it is everything in the day to day life, it's somehow connected to math, so I feel being able to see for ourselves just how much math matters. It made math make sense.

I: so what can you say about math trail in general?

R2: it's a great way to learn math, its great way to understand math, it brings a lot of meaning to math and personally I felt like most of the students liked it but of course I can't tell for everyone. But generally we all had fun doing math outside of the classroom. So if this worked upon to be included in the curriculum it will really benefit we the students.

R2: it was really fun doing this with the class.

I: don't you think it's because you don't go out to do tasks that is why you think mathematics is abstract?

R3: yeah. Because I will be more motivated to learn because I know how to use it in real life instead of just using it in a book and don't see the point of doing those tasks.

I: so if you had enough time, would have liked to complete the tasks

R3: yeah. We just had one task left so it would have been fun completing that one but because it was raining it was not possible.

I: what are some of the benefits you got from the activity?

R3: it was fun completing the tasks, doing it in a group, I don't really know if these are benefits.

I: did you need other materials that were not provided?

R4: yeah, we wanted the other type of measuring tape. That would have made the measurements simpler. Although the measuring stick helped us in measuring, it also took a little bit longer.

I: If mathematics or mathematical tasks are to be carried out of the classroom,(like you learn about the area and you are given a task to find the area of a field where the measurement is done by you) will it help you understand mathematics better and also better appreciate the value of mathematics?

R4: yeah, because then we get to see how we can use the mathematics in different situations and not just an example in a text book.

I: did you benefit from the activity?

R4: yeah, I got to move about instead of just sitting in the classroom and it was fun

I: were the mathematics involved more or less? Do you think we should have included more mathematics or we should have reduced the mathematical content? Or do you think we should have introduced that that you have learnt only?

R4: yeah it should include the topics we've been through so that we can get the understanding quite well and to also see the tasks done from a new perspective by doing it outside the classroom.

I: did you need any material other than what were provided?

R5: measuring stick was really short, so we measured without the stick but we got it right eventually. We could have used the stick but it was going to take time and it was raining as well. We didn't use the writing pad but rather the calculator and the stick.

I: so what can you say about the activity that is the math trail in general?

R5: I would say the weather was the most horrible factor, I felt like the measuring tasks and the counting tasks were just useless. Because we all know how to measure and count, its just basic math. But for other tasks like the circumference of the circle, the slope, we had to think and that was when we were doing the real math and was useful. Because you have to think how am I going to do this thing and not just some straight forward, tasks.

I: do you think that such activities should be included in your curriculum?

R6: yeah, I think so. Because sitting in class is just getting boring, so for a while it's just important for students to just go outside and working with mathematics and this will make mathematics really interesting and always sitting in the classroom. And its very beneficial for students.

I: was it difficult getting the mathematical ideas behind the tasks?

R7: we didn't understand what the description meant, an example is the tasks at the bicycle ramp.

I: were the materials provided sufficient for you?

R7: yes. In some cases, it was a little bit too short. There was a question to check the length of something but they didn't say exactly what?

I: was the activity useful?

R7: in my opinion, for me, it will be more effective to sit in the classroom, because if you give more information on what is outside, it can be done in the classroom. With the parking thing, you had the task that you just have to count the total, so in the class, you have counted the total and state it the question for us to do the rest of the tasks in the classroom. Because those who actually work with mathematics don't go outside doing these counting and checks outside. The plus was that you are moving so you don't sleepy as you would, when working in the classroom and would also love it if we could run from post to post because I love sports.

Appendix 5 Pre-service teacher's math trail

Tasks

THE BICYCLE PARKING AREA

1. How many bicycles can occupy this parking area?

2. In 2021, there were 1600 students and 200 teachers at KKG. If 80% of this population decides to come to school with bicycles, how many of this parking lot will be needed?

3. Do you see the rectangular field from entrance 3.1 to 3.4 (towards UiA)? Suppose people are stand in this area while observing the 2meter social distancing, estimate, how many people can gather here?

THE WHITE BUILDING

4. The building regulation demands that the slope of a wheelchair ramp is not steeper 1:12. Is this wheelchair ramp at the white building designed to suit this regulation?

5. Do you see the line trees in front of the white building with approximately the same heights? Estimate the height of the tree.

THE ODDERNES CEMETERY

Go into the Oddernes cemetery in the direction towards UiA and find the yellow signboard.

6. Estimate the number of graves that can be dug in this area.

7. from the years 2017 to 2019, 387 graves have been buried in this new Oddernes cemetery. How many years do you think it will take for the area that you measured to be filled with graves?

DIVERSITY

8. 16 August 2019, a pedestrian crossing in rainbow colors was inaugurated to celebrate diversity at UiA. Surveys in different countries say that the percentage of LGBTI+ people among any population is 4-7%. At UiA, there are 13 690 students and approx. 1500 staff members.

Approximately, how many students and staff at UiA will be LGBTI+?

FIRE ESCAPE

9. The 2nd, 3rd and 4th floors of Building D have an emergency escape on the east.Imagine there are 200 people on each floor, and there is a sudden emergency that requires all to take the staircase. How long will it take for 600 people to run down?

a. Interview guide

This interview is being done as part of the data collection for Jennifer Ntim's master thesis; ''Students Mathematization through math trail: its benefits and challenges''. You are taking part in this interview because you participated in the math trail activity. I would plead with you to give honest answers as much as possible and anonymity of this information is secured. You can hold me responsible if your voice is being played anywhere or your data is used for any other purpose apart from the purpose of carrying out this research.

You can have your tasks with you for reflection of what happened during the activity.

This interview consists of three parts. The first part is about the challenges you faced, the second part is about the benefits you derived, and the third part is about your opinion on what could have been done to make the activity much better.

1. Which group are you representing?

CHALLENGES

This section seeks to find out the difficulties and hardships you encountered while carrying out the activity.

2. Was it difficult finding access to the place? What are your reasons for your answer?

3. Was it difficult trying to understand the task? What are your reasons for the answer?

4. Was it difficult finding the mathematical idea behind the task?

5. Was it easy to understand the terms used in the question?

6. Were the materials provided to you relevant for the activity? Did you need any special material which you did not have at hand and made your work difficult?

7. Was the weather a challenge for you?

8. Were the tasks boring?

9. Apart from the above challenges asked, did you encounter any different kinds of challenges?

BENEFITS

This section looks at the benefits you derive when having a math trail activity

10. If mathematical tasks are to be carried outside the classroom in activities like this how will it make the mathematics meaningful? Did you realize that mathematics is around us everywhere in the community?

11. Do you think this activity will make students understand some of the topics that you learnt better?

12. As a teacher would you like to use this math trail activity to introduce a topic or make a topic more understandable for students?

13. Do you think this activity will make mathematics meaningful to students?

14. Do you think the tasks were below or above(your) the standard of the students? Was the math trail activity helpful to you as a student? What are some of the benefits you had through the math trail?

15. What are other benefits you derived apart from those mentioned?

OPINIONS

In this section, I would like you to share your views about the math trail activity as future mathematics teachers.

16. What do you think should be added to this activity to make it more beneficial to students?

17. From your point of you, do you think this task is beneficial to students? How are they beneficial to the student?

18. Do you think all mathematical topics can be included in math trail?

19. What do you think should have been added to the activity or should have been avoided?

20. If you are to plan such activity for your students, what would you consider?

21. What can you say about math trail? Its benefits and challenges.

EXTRA

Questions for Cengiz.

22. As you were observing and listening to the students as they work, did they express any difficulty or joy while solving the tasks?

23. What are some of the difficulties you saw the students faced while carrying out the activity?

24. How beneficial was the activity to the students?

c. Transcripts

CASE B TRANSCRIPTION

I: the weather was quite lovely because there was much sun. I think we had to change our day for the activity because it was going to rain heavily on that day. But then do you think it would have

been okay if the weather was snowy, rainy or anything otherwise do you think it will be a challenge?

L: maybe when it is raining and cold or slippery, or snowy, the time we spend outside might be limited. Because if you are doing this task with young kids we don't want them to get wet or cold so it may not be the best to have it in bad weather.

I: so apart from the questions that have been asked about the challenges, do you encounter any challenge apart from the ones that have been asked?

L: one practical problem was the at the emergency fire escape. We were the first group and we solved the task, but I don't any other group can solve it after us. Because after us, the door was locked. So they may not be able to do the experiment of running up and down the stairs at the emergency exit.

I: to what extent do you think that will assist pupils to understand some mathematics topics learnt much?

L: 100%. It will help them understand proportions, measurements of distance, time, area etc. it makes those concepts meaningful.

I: so how beneficial do you think this activity was to your students?

L: it was beneficial, they learnt another teaching strategy as future mathematics teachers.

I: so would consider this math trail activity to become a permanent part of your course?

L: yeah, I may reserve a whole week for this activity next year. In summary I think all the students enjoyed the activity. I would prepare worksheets for them to write their solutions on them and also ask them to make reflections of what they have done.

I: was it difficult finding access to the places?

T1: no I think it was easy, the GPS told us where we were going and how far we were from our targeted location. That was very great.

T2: we actually misunderstood the bicycle parking lot, we hurriedly read the description of the location, so we went to the bicycle parking lot at the entrance of UiA but later we realized that it was at KKG so we had to go back. It was our mistake.

I: to what extent do you think this activity will help some mathematical topics like geometry and measurements better understood?

T1: I think they benefit from actually taking the measurements themselves, and not only using centimeters but then they get to see how big it actually and that is interesting.

I: are there any other benefit that you derived apart from the ones mentioned?

T1: physical activity is one of the beneficial side of the whole math trail activity. And for children that have energy and have a difficulty sitting at their desk, it will help them move their body and I think they will like that.

T1: it was fun to collaborate with each other and not doing it alone.

T2: we were three in our group and that was a great amount for these tasks. Someone can write, other can measure, and another can count. And everyone in the group had something to do. And it really promoted teamwork.

I: which tasks was difficult to understand?

T4: I think the fire escape tasks was hard. It was a lot of estimating and we didn't know how high the stairs were, so we were a little bit unsure when we were answering the questions and the information was not also enough.

I: was it difficult finding the mathematical idea behind the task?

T3: yes, I think so.

I: which of the tasks was difficult getting the mathematical idea behind it?

T3: it was difficult to understand the tasks at the fire escape and we also had a problem with the white building task with the tree, because when we were estimating how high the tree was, we found out it was a little bit more than 300cm and the answers were I think only from zero to two hundred. So we didn't know if it in meters or centimeters. Then we assumed that the answers were in meters, but we were wrong, and we couldn't really understand what you were asking about.

I: do you think this activity will make students understand some of the topics that you learnt better?

T3: yes, it is possible. You need to know the shape of the area, and that is geometrical, and the shapes of the grapes, and all the measurements and estimations were very good. It is a good alternative for classroom learning, because the pupils are able to see for themselves and not just draw rectangles in their books.

I: as a teacher would consider this math trail activity?

T3: yes, but I will use some of your tasks but will also use different questions. I think it is good that the pupils learn around and also use their body. If I am to plan a trail, I will consider percentages geometrical fields,

T4: I agree with T3 and I think this math trail is good, because you don't have to sit in the classroom and do tasks. You also go to a new environment and the teaching method also changes.

I: Which tasks are beneficial to pupils? How are they beneficial to pupils?

T4: The task at the cemetery is a good task for students, it requires at least mathematical understanding. The task at UiA at the colored transition field is also an interesting task for the students who can also provide more knowledge about the society we live in, today.

I: if you are to plan such activity for your students, what would you consider? If the participant does not answer spontaneously, a hint can be to think of group composition, avoiding phones in primary school, avoiding competition between pupils.

T4: Specific questions and accurate information on the answer page are important. For example, the problem by measuring the tree, then the answer page should tell us whether we should state the answer in cm or m. The problems should also be made so that all students can experience mastery. You may want to focus on customized training, and for those who need extra challenges, this can happen in the classroom.

I: was it difficult finding access to the place? Which was the hardest, and why? Which one was easiest and why?

T5: I think we did find some difficulties especially when we were supposed to go to the church, we thought it was close to the yellow sign and the task at the white building we got the points for

finding the location quite early but the building was a little further but not too far. The challenge is, it wasn't exactly at the location where the points were awarded.

I: so it means you got to the place but getting the point was the challenge.

T5: yes, because we got to the white building, but we had to come back to some point before the we could get our points for finding the location. Finding the white building wasn't the problem actually because we could see the picture of it in the app, but getting the award for finding the location was the challenge, because we needed that to continue.

I: was it difficult trying to understand the tasks? Which one was hardest and why? Which one was easiest and why?

T5: not so much, but the one at the church was a little bit hard, we were supposed to measure the field, but we didn't quite understand where we were supposed to start with the measurement. wasn't from the nearest end to the yellow sign board or from the farthest end to the yellow sign board.

I: so you couldn't figure out whether you were to begin the measurement from the nearest grave or from the farthest end of the grave yard.

T5: yeah.

I: was it difficult finding the mathematical idea behind the task? For which task was it hardest, and why? For which one was it easiest and why?

T6: no, not at all. I really liked the ideas of all the tasks, the fire escape task was a bit difficult to estimate or calculate, because we didn't have access to it and it was pure guessing. But I do like the fact behind all of the tasks and ow everything made sense mathematically.

I: to what extent does this activity assist pupils to understand some mathematical topics like geometry or measurement better?

T6: I feel so. I feel like making them see shapes and paradigms in everyday life will make them more curious to be making their own little tasks and solving them mathematically and also sharing it with others will be fantastic.

I: what are other benefits and limitations of my KKG-math trail you derived apart from those mentioned?

T6: one of the benefits for me is that, students can take pictures of their solutions and then we can discuss in class, the different strategies they used in deriving their answers. One limitation will be that if you have a large class managing the groups will be kind of hard, but we can as well limit the distance and maybe have it at a playground or around the school