MOBILE-SUPPORTED OUTDOOR LEARNING IN MATH CLASS: DRAFT OF AN EFFICACY STUDY ABOUT THE MATHCITYMAP APP

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Abstract. *Both, mobile learning and extracurricular learning, offer great potentials for mathematics education. An interesting approach which combines those two concepts is the math trail idea: Students work outside on mathematical problems related to real-existing objects. Thereby, the mathematical learning progress can be structured by the MathCityMap app. The app guides students to the task situations, shows the task and gives hints. The subsequent described study shall examine the possible impact of long-term mobile-supported outdoor learning on mathematical skills by using the MathCityMap app. Therefore, twenty classes of eighth graders (Hessian Gymnasium) will be accompanied in the school year 2020/21. While one experimental group works on math trails by using the MathCityMap app, a second experimental group will work on a paper-and-pencil math trail. Within five tests, the learning progress of both groups will be compared among each other's and with a control group.*

Key words: Efficacy Study, Extracurricular Learning, MathCityMap App, Math Trails, Mobile Learning

CONCEPTUAL FRAMEWORK

Mathematical education in school should enable students to acquire long-term mathematical competencies. Two promising didactical approaches – namely mobile and extracurricular learning – will be presented in this section. The mobile-supported outdoor learning, which is the intersection of both didactical concepts, will complete the theoretical introduction.

Learning in a digital world: Digital Media and Mobile Learning

Digital Media are defined as "media which save or transfer information by means of electronic devices and replay them in an iconic or symbolic representation" (Pallack, 2018, p. 28; translation by SB). In the educational field, their usage raises numerous expectations. For instance, Krauthausen (2012) mentions the higher level of student motivation, the possibility of playful and discovery-based learning as well as potentials for internal differentiation.

Drijvers, Boon and Van Reeuwijk (2010) name two functions of digital technology. They distinguish 'Do Mathematics' and 'Learn Mathematics'. 'Do Mathematics' means that the digital device takes over an activity which could be carried out by the student manually. 'Learn Mathematics' is split into the aspects 'Practicing Skills' (training function) and 'Developing Concepts', which focus on the development of mathematical understanding.

Mobile learning is characterized as the usage of smart devices like tablets or smartphones in an educational context (Park, 2011). The computing power and portability of these devices as well as the possibilities of wireless communication and digital tools offer great potential for both traditional classrooms and extracurricular learning (Sung, Chang, & Liu, 2016). Based on the named arguments, many expectations are linked to the idea of Bring Your Own Device (BYOD) which describes the usage of students' private mobile devices for educational purposes. The large availability of private mobile devices – in Germany 97

Barlovits, S. & Ludwig, M. (2020). Mobile-Supported Outdoor Learning in Math Class: Draft of an Efficacy Study about the MathCityMap App. In M. Ludwig, S. Jablonski, A. Caldeira, & A. Moura (Eds.), *Research on Outdoor STEM Education in the digiTal Age. Proceedings of the ROSETA Online Conference in June 2020* (pp. 55-62). Münster: WTM. https://doi.org/10.37626/GA9783959871440.0.07

percent of the 12 up to 19-years-old teenagers own a smartphone (Medienpädagogischer Forschungsverband Südwest, 2018) – indicates that students are well-trained in the handling of those devices. In contrast to the usage of foreign devices, BYOD can minimize operating problems (Schiefner-Rohs, 2017). However, some challenges inherit the concept of BYOD. Firstly, different operating systems like iOS or Android may lead to technical problems. Secondly, BYOD urgently calls for a boost of students' media competence. In total, BYOD offers many potentials for the educational field but has to be integrated with caution to take advantage of it (ibid.).

Learning in one's own environment: Extracurricular Learning

A unified definition of extracurricular learning does not exist, however all educational activities outside the classroom are subsumed under this term (Sauerborn & Brühne, 2014). Therefore, extracurricular learning takes place whenever students work outside the school on "an original learning topic under aimed pedagogical instruction" (ibid., p. 11; translation by SB). For this study the following definition will be applied:

> "Extracurricular learning […] means a recurrent, in the school routine integrated teaching concept. It includes the immediate, natural environment of the children (as learning environment) by teaching curricular contents and it is closely related to regular lessons in the classroom" (Sitter, 2019, p. 73; translation by SB).

Collecting first-hand experiences, working on real problems and integrating discovery learning are the most important benefits of extracurricular learning (Karpa, Lübbecke, & Adam, 2015). Even though those didactical concepts are important for students' mathematical education, a specific mathematical extracurricular learning concept is still missing. In addition, most research projects about extracurricular learning in mathematical didactics focus on Science Centers (Sitter, 2019).

A promising approach for mathematical extracurricular learning is the idea of math trails. A math trail is a route which consists of several place-bound math tasks, which treat mathematical questions about real existing objects (Cross, 1997). Hence, students can perceive their own environment from a mathematical perspective. Furthermore, students are able to apply their mathematical skills in many different situations which leads to a deeper mathematical knowledge (ibid.). Shoaf, Pollak and Schneider (2004) highlight the value of collaborating. Furthermore, they emphasis that people of all ages can walk and work on a math trail (ibid.).

Digital learning in the own environment: MathCityMap Math Trails

After analyzing the benefits of both, mobile and extracurricular learning, those two approaches will be combined in the term of mobile-supported outdoor learning. This term describes the usage of mobile devices to support learning processes outside the classroom.

The MathCityMap app combines the idea of math trails and technological potentials of smartphones (Ludwig & Jablonski, 2019). The app guides students by GPS navigation to the next task, shows hints and gives immediate feedback on the correctness of a student's solution. Depending on its quality, groups receive up to 100 points per task. The system also provides a sample solution. When using the MathCityMap app, students should work together in groups of three. Only one smartphone or tablet with the installed app (available and free of costs for iOS and Android) is necessary in each group. For that reason, the app could be used for BYOD-based math class (ibid.).

By using the MathCityMap app, the smartphone covers both functions of digital technology, which are described by Drijvers et al. (2010). The smartphone itself can take over the function ‘Doing Mathematics’, e.g. when the installed calculator is used. On the contrary, the MathCityMap app also fulfills the function of ‘Learning Mathematics’. As the examination of interesting, real existing objects is the core of the MathCityMap idea, MathCityMap tasks are target to practice students’ mathematical skills. Depending on the task formulation, working on MathCityMap task leads to a deeper understanding of mathematical concepts. The following figure illustrates how tasks presented by the MathCityMap app can take over the function 'learning mathematics' with its aspects of practice and concept development.

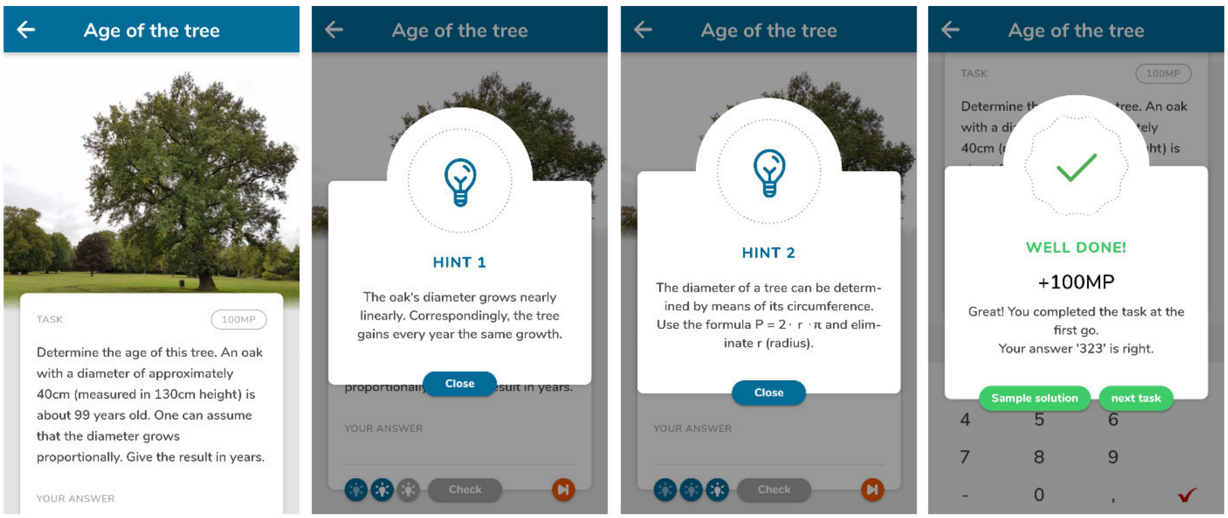

Figure 1: Presentation of math trail tasks by the MathCityMap app.

STATE OF THE ART

The MathCityMap app provides two useful tools, namely the gamification feature Leaderboard and the organizational feature Digital Classroom. Both tools will be described in the following. In addition, the work of Zender (2019), which should be extend by this study, will be summarized.

The optional feature Leaderboard, which lists the reached points for each group in a ranking, leads to a significant higher motivation of the students (Gurjanow, Olivera, Zender, Santos, & Ludwig, 2019). It also seems to increase the rate of completed tasks per hour. By using the feature Leaderboard, 3.4 tasks per hour were completed in average, whereas students only work on 2.8 tasks per hour, if no gamification element was used (ibid.). Furthermore, the Leaderboard feature reduces blind guessing significantly because the achievable number of points for solving the tasks decreases after the third wrong answer. Without gamification, 3.8 answers per tasks were entered into the MathCityMap system (SD = 3.2). If the Leaderboard is used, students input 2.0 answers in average (SD = 2.0; ibid.).

If the used mobile devices have internet access, teachers can retrace the students’ progress of the math trail via the MathCityMap tool Digital Classroom. The feature provides a chat which enables teachers to communicate with all student group. In addition, it transmits the present location of each group to the teacher and indicates how many tasks were solved by the group. “In alignment with privacy and data protection, it allows the teacher to see the actions of the pupils during the maths trail activity" (ibid., 3), which could pave the way to an effective follow-up of the math trail.

According to Zender (2019), the usage of the MathCityMap app not only leads to a higher degree of motivation, but also to a better performance in mathematical tests. In a study with more than 500 German ninth graders, he could show that those students, which used the MathCityMap app for working on cylinder tasks, reached significantly better test results than the control group (Cohen's d = 0.8). This indicates a positive short-term effect of the mobile-supported outdoor learning with MathCityMap.

Zender (2019) also analyzed the long-term impact of math trails. In the follow-up test the experimental group could replicate the results of the post-test, whereas the results of the control group clearly decreased (d = -0.8). However, only 64 test persons (22 of the control group; 42 of the experimental group) have completed the follow-up test. Overall, those results suggest a positive long-term effect of extracurricular learning by using MathCityMap (ibid.). Nevertheless, a deeper investigation seems to be necessary. The below described study should close this research gap.

MOTIVATION AND RESEARCH QUESTIONS

The research project pursues the empirical target to analyze the short- and long-term learning progress of students in mathematics by using both mobile and extracurricular learning repeatedly. From a theoretical position, the study focusses on possibilities to embed the math trail method in regular school classes. The following research questions should be answered as a result of the study.

Embedding of MathCityMap math trails

- How could math trails be embedded in regular school lessons?

So far, math trails are often used and well-tested for the revision of learned content. Therefore, MathCityMap math trails usually cover a wide range of mathematical topics. In the framework of this study, theme-based math trails should be created. A math trail is defined as theme-based, if at least every second tasks refers to one special mathematical content.

The first theoretical outcome of the study will be an analysis of the Hessian curriculum and school books (eighth grade of the Hessian Gymnasium) to develop characteristic task types for theme-based math trails. Those theme-based trails will be created as a basis for the later empirical analysis of students' learning progress by using the math trail method.

- How an effective preparation and follow-up of math trails can be realised?

To stimulate and strengthen the outcome of extracurricular Learning, its embedding in the regular class is essential (Sitter, 2019). The necessary preparations for extracurricular learning include organizational, didactical and content-related parts. Sauerborn and Brühne (2014) name the scheduling of the activities as well as obtaining the essential approvals (parents and school management) as the main organizational challenges. The didactical preparation encompasses the topic at hand and the learning goal, while content-related parts refer to the introduction of the extracurricular learning in class. The follow-up is characterized by students' reflection about the extracurricular learning and by securing its main contents (ibid.).

Until now, a detailed conceptualization about preparations before and follow-up after a math trail is missing. For that reason, a second theoretical output of the study will be the development of such a concept.

Impact of MathCityMap math trails on students' learning progress

- Which impact has the usage of theme-based MathCityMap math trails in mathematics on the short-term learning progress of eighth graders?

In the described study of Zender (2019), ninth graders worked once or twice on a theme-based trail about cylinders. His research indicates a positive influence of MathCityMap on students' handling of applied math tasks. In the framework of this study, this observation shall be verified for eighth graders of the Hessian Gymnasium. However, the center of the study will be the following research question:

- Which impact has the long-term usage of the MathCityMap app in mathematics on the long-term learning progress of eighth graders?

The research project should not only replicate but extend the study of Zender (2019). Eighth graders of the Hessian Gymnasium shall work for one school year periodically on theme-based math trails using the MathCityMap app. The aim is to analyze the influence of mobile-supported outdoor learning using MathCityMap as an example.

METHODOLOGY

To analyze the long-term effect of repeated mobile-supported outdoor learning by using the MathCityMap app, approximately twenty classes will be accompanied in the school year 2020/21. The study includes one pre-test, four treatment phases and a final follow-up-test.

At the beginning of the school year 2020/21, the pre-test is carried out. The mathematical knowledge of the eighth graders (Hessian Gymnasium) is tested by past items of the German comparative study VERA-8. The test comprises a wide range of already learned mathematical topics from arithmetic, algebra, geometry and basic stochastical problems. Based on the results of the 90-minutes pre-test, the classes are divided into two experimental groups and one control groups (Table 1), so that all three groups possess a similar distribution of mathematical skill among the students.

Both experimental groups, consisting of ten respectively of five classes, work twice on theme-based MathCityMap math trails concerning four different topics. Whereas the Experimental Group I (EG I) uses the MathCityMap app including the app features hints and feedback, the Experimental Group II (EG II) works on the math trail with the 'classic' paper-and-pencil method. Thereby, both groups receive the same task formulations; once via digital media (EG I) and once by a printed trail guide (EG II).

The control group (CG), which consists of five classes, works on applied tasks inside the classroom. Those tasks are designed similarly to the math trail tasks including hints and sample solutions; however, the measured data are given in the task formulation. To allow the comparison of EG I and the control group, the tasks are presented by the MathCityMap app. In addition, a didactic analysis of the tasks presented to the students in the different settings (EG I: with app outdoors; CG: with app inside the classroom) seems to be necessary before starting the study.

We decided to dispense with further control groups to prevent an unnecessary expending of the study design. Several empirical studies (e.g. Reinhold, 2019) showed in the last years that the usage of digital media, respectively of apps, per se has no effect on the learning progress of students of the German Gymnasium. By implication, this indicates that the learning progress of students inside the classroom does not primarily depend on the media by which the content is presented. Therefore, we assume that our analysis of the control group can be easily transferred to the work on applied tasks which are given in a printed version.

Experimental Group I	10 classes	math trails	MathCityMap app
Experimental Group II	5 classes	math trails	printed trail guide
Control Group	5 classes	applied tasks	MathCityMap app

Table 1: Design of the experimental groups and the control group.

During the four treatment phases, each group receives two treatments of a double lesson each time. In total, the study includes treatments of eight double lessons plus pre- and post-test (Table 2). Every treatment is referred to one topic of the Hessian curriculum for the eighth grade. The four identified topics for eighth graders of the Hessian Gymnasium, which can be covered by theme-based math trails, are linear functions, interest calculation and basic stochastical problems. The fourth topic is referred to the Hessian comparison test Mathematikwettbewerb, which takes place at the end of the first half-year and includes arithmetic, algebraic, geometric and stochastic tasks.

<table>
<tr><th colspan="3">2020/21
1st half-year</th><th colspan="2">2020/21
2st half-year</th><th>2021/22
1st half-year</th></tr>
<tr><td rowspan="2">pre-test</td><td colspan="4">two treatments á 90 min per topic</td><td rowspan="2">follow-up test</td></tr>
<tr><td>linear functions</td><td>comparison test</td><td>interest calculation</td><td>stochastical problems</td></tr>
</table>

Table 2: Timetable of the planned study in the school year 2020/21.

After completing a topic, a performance test of 45 minutes is conducted (Table 3). Each test consists of several applied tasks concerning the learning content. This allows us to identify the students' short-term learning effect on this topic. In addition, it enables us to compare the learning progress of the three groups.

Three months after the last treatment (beginning of school year 2021/22), a 90-minutes follow-up test is carried out. All items of the follow-up test are taken from the performance tests. The follow-up test has two functions. Firstly, this proceeding enables us to compare directly the students' results of the performance tests and the follow-up test. In other words, the repeated use of the test tasks documents the students' recollection of the four topics, i.e. their long-term learning effects. Secondly, a comparison of the pre-test and the final test makes it possible to analyze each student's learning progress – and thereby the absolute learning progress of each group, too.

Experimental Group I	two double lessons á 90 min	MathCityMap math trail	performance test á 45 min
Experimental Group II		‚classic' math trail	
Control Group		applied tasks	

Table 3: Procedure of the four treatments.

The two empirical research questions contain implicit the question after the influence of mathematical extracurricular learning, mobile learning as well as the impact of mobile-supported outdoor learning on students' learning progress.

To analyze the role the math trail method, we will compare the test results of EG I and the control group. As both groups work on similar applied tasks which are presented by the MathCityMap app, we are able to identify the variable 'math trail'. The impact of mobile learning can be examined by comparing the two experimental groups. Overall, we expect that this study design allows us to analyze how mobile-supported outdoor learning influences the mathematical learning progress of students.

EXPECTED RESULTS

The described study shall extend the work of Zender (2019), which shows a positive shot-term learning effect of MathCityMap math trails. It also indicates that the usage of MathCityMap math trails has a positive long-term influence on students' handling of applied math tasks. We assume that this learning effect is caused by first-hand experience and the students' necessity to collect data themselves. Therefore, we expect both a better short- and long-term test performance of the two experimental groups in comparison to the control group, which works inside the classroom on applied tasks. To formulate this hypothesis in regard to the conceptual framework, we assume that extracurricular learning by using the math trail method deepens and reinforce the learning experience.

From a theoretical perspective, it can be assumed that using the MathCityMap app (EG I) has several advantages compared to the paper-and-pencil trail guide (EG II), especially the possibility to call up stepped hints, to get an immediate feedback on the correctness of the solution or to show the sample solution (Ludwig & Jablonski, 2019). Both features can students help to structure and to organize their work progress and to validate their solution subsequently (ibid.). However, it remains to be seen whether the use of the MathCityMap app will lead to a better learning progress of EG I when comparing the two experimental groups. At least, previous studies on learning with the MathCityMap app suggest that using the app leads to a significant and lasting increase in the motivation of students working on math paths (Cahyono, 2018; Gurjanow et al., 2019).

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