DEVELOPMENT OF AN INTENSIVE STUDY PROGRAMME ON OUTDOOR MATHEMATICS TEACHING WITH DIGITAL TOOLS

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Abstract. *Within the Erasmus+ project "Mobile Math Trails in Europe" (MoMaTrE), a two-week Intensive Study Programme was conducted in March 2019. 30 university students from the field of mathematics education from Germany, France, Portugal and Slovakia got to know outdoor education and the "MathCityMap" system for creating mobile math trails from a student's and teacher's perspective. With a main focus on task design and task review, the students tested their tasks with school classes and made authentic outdoor learning experiences. The following paper presents the aims, contents and schedule of the Intensive Study Programme with special focus on the MathCityMap system. Further, it analyses the evaluation among the students and gives insight into their achievements and experiences with respect to the programme's aim.*

Key words: outdoor learning, math trails, MathCityMap, Intensive Study Programme

THE INTENSIVE STUDY PROGRAMME IN THE CONTEXT OF THE MOMATRE AND MATHCITYMAP PROJECT

Authentic tasks should be a noticeable part of mathematics school lessons (e.g. Borromeo Ferri, Greefrath & Kaiser, 2013). Following the definition by Vos (2015), an authentic task should be created in an "out-of-school origin" and needs a "certification" (Vos, 2015, p. 108). Mathematics tasks are frequently proceeded inside the classroom with help of a picture and/or textual information. Such a mathematical task refers to an authentic object, but is in many cases adapted to the educational context. Here, the authenticity in the sense of an out-of-school origin and a certification is obviously (at least partly) not guaranteed. Leaving the classroom for mathematics education can play an important role in the implementation of authentic mathematics tasks. One option of outdoor mathematics is to do so called "math trails". A math trail is a walk where one can discuss and solve mathematical tasks (Shoaf, Pollack & Schneider, 2004). To solve a task, it is absolutely mandatory to leave the classroom because mathematical interaction with the task object at the object's location is required (Ludwig & Jesberg, 2015).

Originally, math trails were not created with the intention to teach mathematics. Further, they were solved solely with paper and pencil. The concept of math trails is nowadays enriched with possibilities of mobile devices to automatically give feedback and allow guidance throughout the trail. Hereby, the idea is led into an educational setting (Gurjanow, Jablonski, Ludwig & Zender, 2019). Despite positive findings regarding the impact on long-term learning and the motivation of learners (Cahyono, 2018), (prospective) teachers raise concerns regarding the organization and implementation, especially due to a lack of experience with this teaching method. This requires theoretical and empirical considerations, which are provided within the Erasmus+ project "Mobile Math Trails in Europe" (MoMaTrE, www.momatre.eu).

The MoMaTrE project started in 2017 with a project duration of three years. The consortium contains seven partners:

- University Constantin the Philosopher Nitra (Slovakia)

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- University Claude Bernard Lyon 1 (France)
- Federation of Mathematics Teachers Societies (Spain)
- Institute Superior of Engineering Porto (Portugal)
- University of Lisbon (Portugal)
- Autentek GmbH Berlin (Germany)
- Goethe University Frankfurt (Germany)

On the one hand, the project provides material and digital tools for teachers to easily create outdoor mathematics activities in their mathematics classes. On the other hand, it supports lecturers to create courses for university students in the field of educational studies in order to teach them how to enrich their future classes with mobile outdoor mathematics activities.

During the project, the ideas and advantages of outdoor mathematics are disseminated through research, workshops, articles and events. One of those events was an Intensive Study Programme which took place in March 2019 at Goethe University in Frankfurt. During two weeks, 30 university students from the field of mathematics education of the partner institutions in France, Germany, Portugal and Slovakia got to know outdoor education by means of digital tools with a special focus on the MathCityMap system.

The MathCityMap System

MathCityMap is a two-component system for realizing out-of-school mathematics learning using digital tools. One component is a web portal (www.mathcitymap.eu) aimed at teachers and authors who can access public tasks and create their own tasks. A task consists of a title, task image, GPS position, solution to validate, sample solution, hints, grade level, and keywords. The system is explicitly adapted to the needs of mathematics tasks. For example, the solution format “interval” tolerates small deviations in measurement and modelling tasks. Furthermore, MathCityMap offers the "Task Wizard", a catalog of pre-prepared and didactically elaborated tasks for frequently occurring questions, e.g. the slope of a handrail in percentage or degrees.

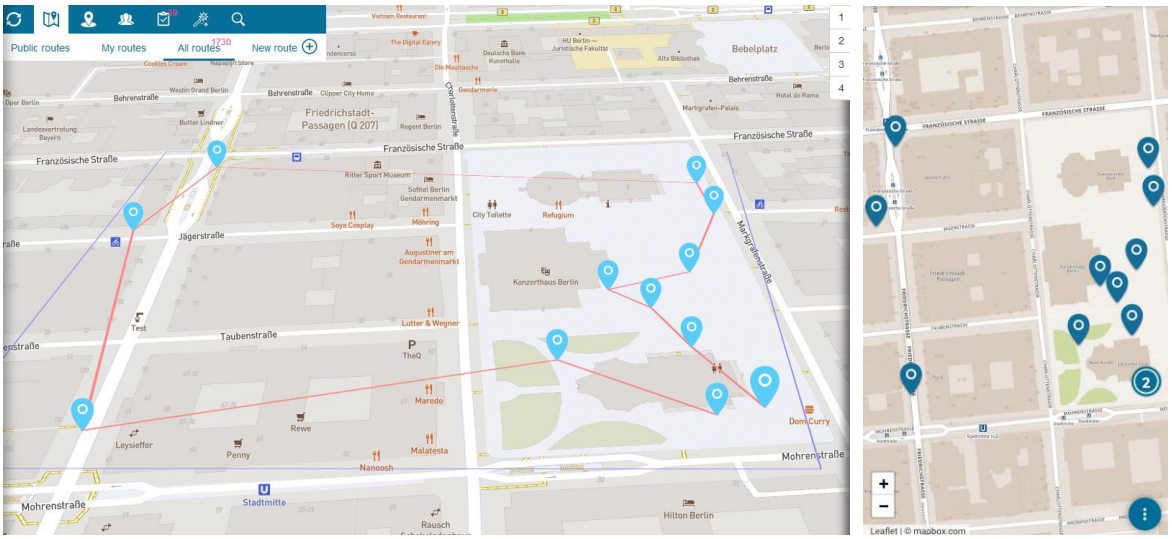

Figure 1: A math trail in the MathCityMap web portal and in the MathCityMap app.

Combining multiple tasks creates a so-called math trail (see Figure 1). A math trail can be enriched with gamification elements such as points or a pirate narrative in which all tasks get embedded. The trail with its features is created in the web portal and then started on the second component – the smartphone app ("MathCityMap" for Android and iOS). The app has – from a student's perspective – the following main features: support of navigation, presentation of the task and the task object, providing previously entered hints, and validation of the solution.

Through these features, it supports the students in their autonomous learning and the teacher in the preparation and organization of a math trail. Especially the "Digital Classroom" gives the teacher the chance to follow the students' working progress and the opportunity to support them individually in a chat while running a trail (for more information see Ludwig, Baumann-Wehner, Gurjanow & Jablonski, 2019).

CONTENTS AND SCHEDULE OF THE INTENSIVE STUDY PROGRAMME

The Intensive Study Programme's underlying aim is that university students of mathematics education get in touch with MathCityMap as an innovative theory-based approach of teaching outdoor mathematics supported by technology. The Intensive Study Programme took place at Goethe University from 18th till 30th March 2019. Each MoMaTrE partner educating university students in the field of mathematics education chose participants for the Intensive Programme with regard to motivational aspects and previously made teaching experiences.

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
Opening and Organization	Lectures: Philosophy and Learning Environments	Lecture: MathCityMap Route	Excursion Mathematikum Gießen	Task Review in Groups	School Visits	Student Activity I	Lecture: Typical Errors in Task Design	Student Activity II	Math Trail Competition
Paper and Pencil Math Trail	Lecture: Task Analysis	Task Creation in Groups					Revise Trail		Final Presentation
Lecture: Outdoor Education	MathCityMap Math Trail		Task Creation in Groups	Feedback on the Tasks	Testing of the Final Trail	Lectures: Augmented Reality and Gamification	Work on Final Report	Work on Final Report	Closing Ceremony
Lecture: MathCityMap	Reflection	Introduction of the MathCityMap Web Portal		Rating of the Tasks	Prepare Student Activity I	Prepare Student Activity II			

Figure 2: Schedule of the Intensive Study Programme.

During the first week (see Figure 2, Day 1 till Day 5), the students learnt about the concept of mathematics trails and how they are embedded in mathematics education (in particular: education outside the classroom). The students received a lot of input from experts from the MoMaTrE consortium as well as invited external experts from the field of outdoor education. The students attended different lectures within the topics of Outdoor Learning, Task Design, Mobile Learning and Additional Features:

- Reasons for Outdoor Education and its Implementation (Outdoor Learning)
- Creating rich learning Environments (Outdoor Learning)
- Analysis and preliminary Analysis of Tasks (Task Design)
- The MathCityMap system (Task Design, Mobile Learning, Outdoor Learning)
- From a mathematical Trail to a MathCityMap Route (Mobile Learning, Outdoor Learning)

- Typical Mistakes when creating MathCityMap Tasks (Task Design, Mobile Learning, Outdoor Learning)
- Gamification in outdoor Education (Additional Features)
- Augmenting MathCityMap for advanced Trails (Additional Features)

Further, they did a traditional math trail without technical equipment and made a first-hand experience of walking a math trail with the MathCityMap app.

After a change in perspective, the students became task creators of their own. In international groups, they worked out tasks for school students on different levels, grades and topics. Firstly, they searched for task ideas in Frankfurt's Old Town. Afterwards, the students worked with the MathCityMap web portal to implement their tasks and create a new math trail for a field test with real school classes. During this phase, the students also learnt about the MathCityMap task design criteria (Jablonski, Ludwig & Zender, 2018), e.g.:

- Uniqueness (the object must be clear)
- Attendance (a task can only be solved at the location of the object)
- Activity (the task solver should be mathematically active)
- Multiple solutions (the task should be solvable in various ways)
- Reality (the task should have meaningful relevance and not appear too artificial)

In preparation for this test, the students conducted a peer review and finally created the tested math trails, both for lower and higher secondary students (see Figure 3).

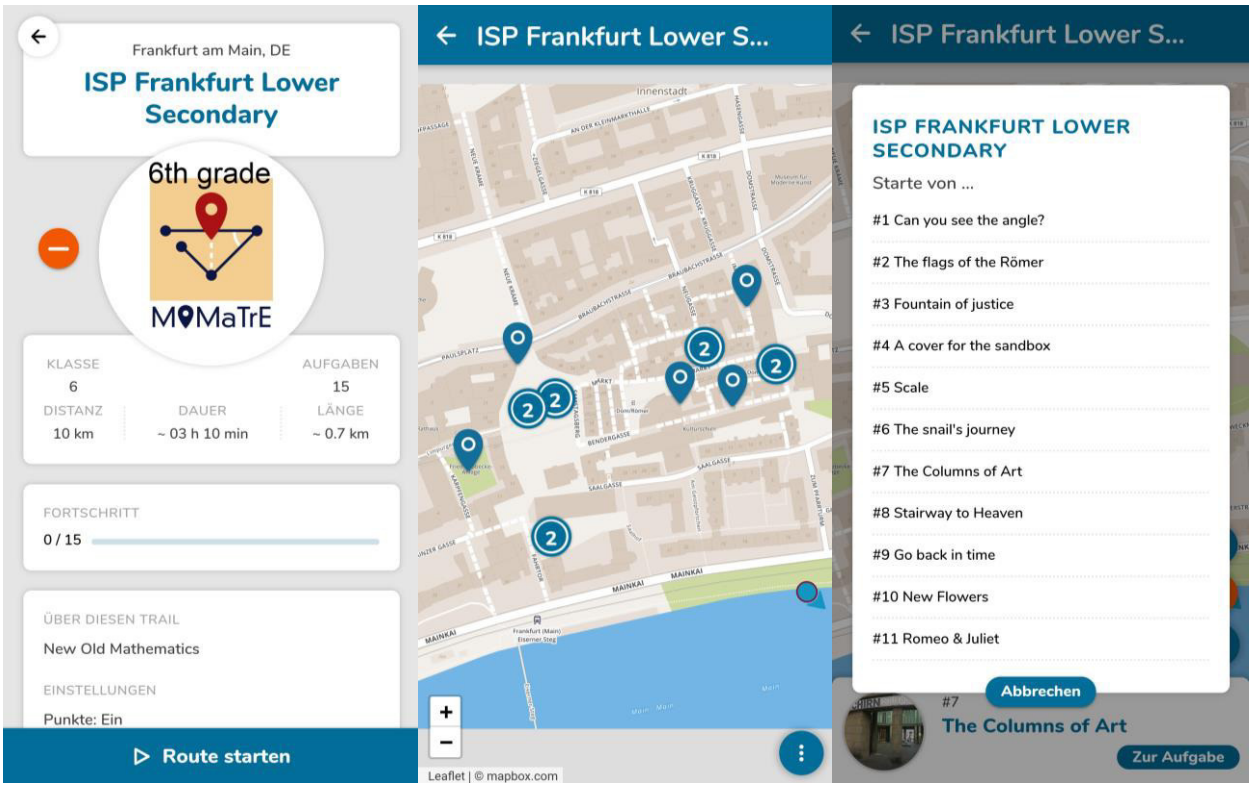

Figure 3: Screenshots of the Final "ISP Frankfurt Lower Secondary" Trail.

During the second week (see Figure 2, Day 6 till Day 10), lower secondary and higher secondary school students joined the course on two different days to do the math trails. These two field experiments were the highlights of the course, since the students experienced their work and themselves in an authentic context. There were two major tasks to be completed by the university students during the field tests:

- Evaluate if their created tasks work as intended, find and implement modifications to improve the tasks
- Make observations according to their previously defined observation focus

Afterwards, the trail events were reflected upon and summarized in the final report and a final presentation of the students. This report was based on daily tasks that the students had to upload every day including short reports on their individual impressions on lectures, activities and events. Further, the students presented and analyzed their individually created tasks and wrote a global reflection on the Intensive Study Programme.

EVALUATION OF THE INTENSIVE STUDY PROGRAMME

At the end of the Intensive Study Programme, the participating students filled in a questionnaire. Their responses as well as their final reflections in their reports are the basis for the evaluation of the Intensive Study Programme. In the following, the evaluating remarks are analyzed in terms of the underlying research question:

Which goals of the Intensive Study Programme were achieved and reflected by the students?

The main goal of the Intensive Study Programme was of academic nature, namely that the students get to know outdoor education and feel competent in its use with school students. Figure 4 shows their positive judgment ("1" very bad, "5" very good) of academic outcomes and that these expectations could be realized during the Intensive Study Programme.

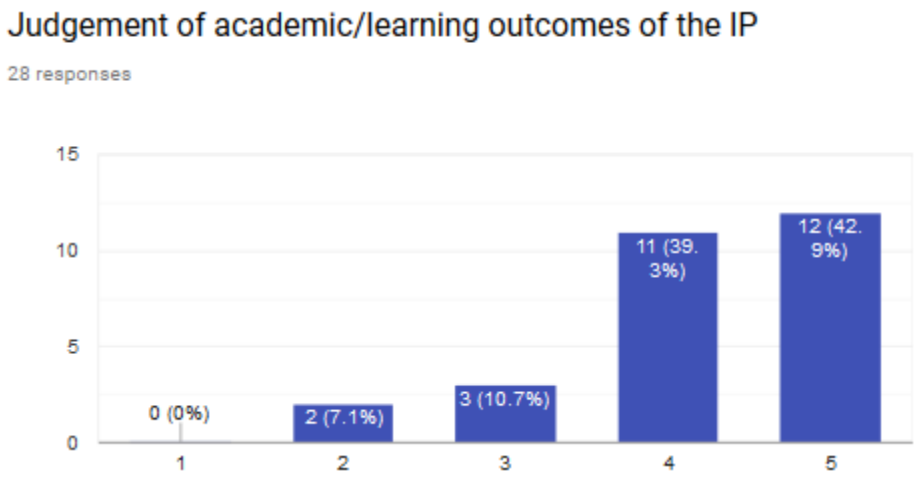

Figure 4: Responses to the Item "Judgement of academic/learning outcomes of the IP".

A strong learning progress can be observed in the design of (outdoor) task. With the first tasks being tested, reviewed, revised and finally tested with school students, the comparison of the first draft and the final task shows that more task criteria were met.

Taking the example of the task "Fountain of Justice" in Figure 5, one can observe the different task criteria:

- Uniqueness: The object is clearly described through the picture and unique at the task's location
- Attendance: The shape of the fountain is not included in the picture, so it is necessary to be at the task's location
- Activity: The task solver has to recognize the (mathematical) shape of the fountain
- Multiple solutions: The task can be solved in different ways, e.g. by means of a sketch, counting or symmetry
- Reality: The task object is a realistic monument in Frankfurt's inner city. The question focuses on recognizing its shape which is not artificial

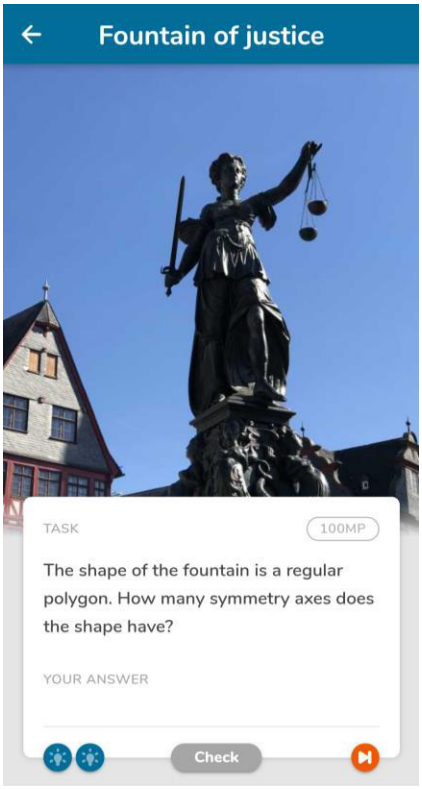

Figure 5: The Task "Fountain of Justice".

With a special focus on the judgement of individual events, the students rated the second visit of the school classes more positively. One can assume that the university students used the feedback and experiences from the first field test, improved their tasks and gained experience in the conduction of a math trail event. This issue can also be observed in some of the final reports. One student reported:

> "When the first class did our final Lower Secondary Trail, they encountered problems and misunderstandings we had not noticed. With the feedback from the students, we were able to solve these problems so that there were fewer difficulties for the class that completed the tasks on the second date. Instead, they were able to concentrate entirely on the mathematical problems to be solved."

The aim of the Intensive Study Programme to educate the university students in the use of outdoor mathematics with MathCityMap seems to be fulfilled. Especially, they had the opportunity to gain practical experiences with the app in two authentic field tests and made realistic observations which are an important basis for future outdoor learning activities. Especially the learning progress within the first and the second activity with school students is a great success as the university students seem to feel more confident in the conduct of outdoor mathematics activities.

Apart from the academic outcomes, the students rated the personal outcomes of the Intensive Study Programme (e.g. practice a foreign language, gain European experiences) very positively (see Figure 6; "1" very bad, "5" very good). Especially the exchange of experiences within four different nations and the chance to visit German school classes was appreciated by the students.

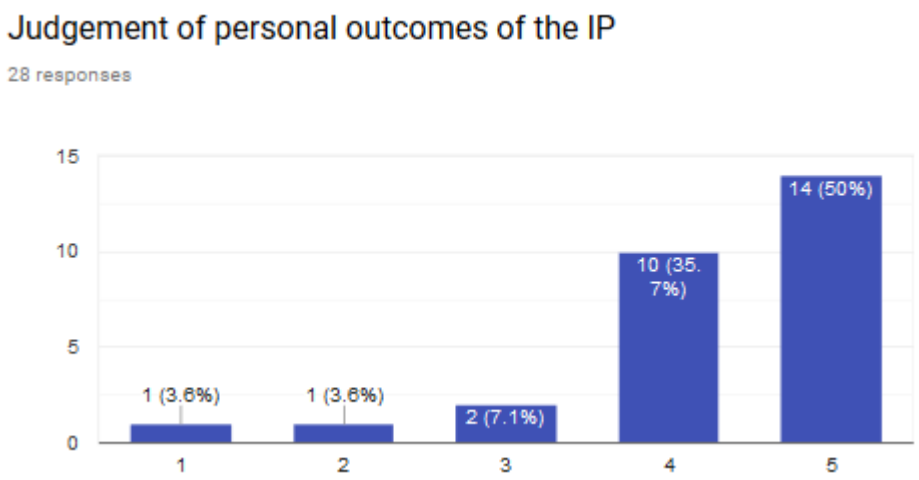

Figure 6: Responses to the Item "Judgement of personal outcomes of the IP"

The questionnaire also asked for opinions on MathCityMap as the system was completely new for all participants. Both, web portal and mobile app were rated as intuitive by most of the students. Solely the interaction between web portal and app was not for every participant easy to understand. The Intensive Study Programme is therefore not only a success for the participating students, but also an important basis for the follow-up of the MoMaTrE project focusing on the continuous development of the usability of the MathCityMap app and web portal.

Summarizing all evaluations and reflections, we can assume that the format of the Intensive Study Programme is appropriate for gaining theoretical and practical experiences in outdoor teaching and learning, for an intercultural exchange on teaching mathematics in Europe, and for getting to know the MathCityMap system with its components web portal and application.

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Figure 7: Group Picture during one of the Student Activities within the Intensive Study Programme.

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