Designing mathematical outdoor tasks for the implementation of The MathCityMap-Project in Indonesia

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Introduction

In the last few years, several countries have seen an increase in interest in the development of outdoor education and adventure education (Fägerstam, 2012; Higgins & Nicol, 2002; Schirp, 2012; Wilhelmsson, 2012; Education Scotland, 2011). Various activities outside the classroom are specifically designed to improve student achievement, and integrated programmes are being developed to combine outdoor learning initiatives with traditional learning in the classroom.

In 1985, Dudley Blaine developed the concept of math trails as one form of outdoor education by creating a trail in the centre of Melbourne, Australia (Shoaf et al., 2004). Math trails take students outside the classroom with the goal of creating an atmosphere of challenge and exploration.

By combining the concept of math trails with advanced technology in a modern learning environment, The MathCityMap-Project, developed by the MATIS I Team from the Goethe University Frankfurt, Germany, provides a new approach to an already well known idea. This project engages students in mathematics on a math trail supported by the use of GPS-enabled mobile phones. In 2013, the project expanded to Indonesia. Its implementation is motivated by the situation and problems in mathematics education in Indonesia.

A closer look at the situation of mathematics education in Indonesia

Indonesian students' performance, both national and international, has not been satisfactory. Several problems need to be addressed, most notably, students' low motivation in learning mathematics. Most of students are math phobic and are happy when the mathematics teacher is not able to come to class (Hadi, 2012).

In the PISA 2012 study, 15-year-old Indonesian students were ranked 64th out of 65 countries, with a mathematics score of 375, and 75.7% of them unable to reach level 2 (OECD, 2013). This means that Indonesian students cannot extract the relevant information of a given task or use basic algorithms to solve mathematics problems. They also have difficulties solving realistic problems, especially in geometry. In the 2012 national exam, the average mathematics score for junior high school students was 5.78 out of a maximum score of 10, and mastery learning for geometry was below 50% (Depdikbud, 2013).

As the first part of the development and implementation of The MathCityMap-Project in Indonesia, a pilot study was conducted in Semarang with the aim of designing mathematical outdoor tasks. To address the issues mentioned above, this study focuses on the question, *'How should mathematical outdoor tasks be designed so that they can be used for the implementation of The MathCityMap-Project in Indonesia?'*

The MathCityMap-Project

Around the world, there are special locations where mathematics can be experienced in everyday situations. Sometimes the locations are hidden and become secret. The MathCityMap-Project provides students with mathematical experiences in real places and situations through mathematical discoveries and activities outside the classroom, supported by modern technological devices (Jesberg & Ludwig, 2012).

Mathematics teachers designed math trails that contained tasks, called MCM-Tasks, based on a variety of topics and places. They linked the tasks to GPS coordinates and uploaded them to the MCM-Portal, where students could access them through the MCM-App. The portal and application can be accessed through the following website: www.mathcitymap.eu.

Figure 1. Interface of the MCM-App

Any public place that allows for a safe walk can provide mathematics problem ideas for imaginative trail blazers (Shoaf et al., 2004). Educators can find reality problems with corresponding GPS data and corresponding hints. The mathematics problems are localised in certain places with the help of GPS coordinates. They deal with a local object or situation, which determines the type of mathematics problem. In the MCM-Portal, teachers can connect the problems to a math trail through the task database and specify the grade, topics, and tools available.

Students complete the math trail using the MCM-App, which shows the task location coordinates, route to the location, tools needed to solve the problem on-site, and hints on demand. After entering their answers, the students receive direct feedback from the system.

The MathCityMap-Project goals are to challenge students to solve problems and enjoy learning mathematics that may manifest motivation. A meta-analysis found that students' motivations and participation in outdoor programmes have a strong influence on their achievements (Hattie, 2009).

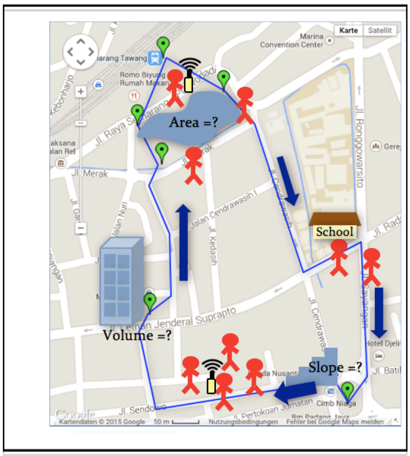

Figure 2. Illustration of the implementation of The MathCityMap-Project

Motivation in Learning Mathematics

Hannula (2006) defined motivation as a potential to direct behaviour that is built into the system that controls emotion. In mathematics, there are several manifestations of motivation: beliefs about the importance of the task, behaviour to extract the relevant information and use basic algorithms for solving problems, challenge of answering the questions, and joy in learning.

Student motivation determines behaviour such as how students initiate problem solving, determine the method, and persist until the end (Coles & Werquin, 2005). The scale of learning orientation consists of five intrinsic or extrinsic aspects: 'preference for challenge versus preference for easy work, curiosity or interest versus teacher approval, independent mastery attempts versus dependence on the teacher, independent judgment versus reliance on the teacher's judgment, and internal versus external criteria for success or failure' (Harter, 1981, p. 300).

Lack of motivation is an obstacle to students' reaching their potential, but motivating students to learn takes effort. Educators need to understand students' psychological and academic needs, and how the learning context affects these needs (Salili, 2001).

The MathCityMap-Project uses authentic tasks to motivate students. Therefore, it is necessary to study the project's pre-implementation in Indonesia to design the MCM tasks. The tasks, if carefully designed and implemented, can increase students' motivation in learning mathematics.

Method

The design research paradigm was aimed at designing the MCM-tasks for the implementation of The MathCityMap-Project in Indonesia.

The study consisted of three phases: theoretical study, exploration, and design. The goal of the theoretical study phase was to formulate an initial theoretical perspective about how mathematical outdoor tasks can be used for the implementation of The MathCityMap-Project in Indonesia. The goal of the exploration phase was to analyse the state of the problems or phenomena and identify appropriate directions. The goal of the design phase was to design the MCM-Tasks based on the results of the previous phases.

The identification phase employed theoretical study research to answer the question, 'What are the mathematical outdoor tasks that can be used in TheMathCityMap-Project in Indonesia?' The methods used during the exploration phase were benchmarking, performance, needs analysis, discussion, interviews, survey of experts, observation, role modelling, and case studies. The methods of the design phase were task analysis, contextual analysis, designer log, expert review, and students' review.

The study progressed in three cycles. The first cycle (CI) was the preliminary design, which included the theoretical study and exploration. Its main focus was the prototypical design of the MCM-Tasks and math trails. The MCM-Task designs were reviewed by experts, and a self-simulation and evaluation session were conducted. The tasks were then revised based on the results. In the second cycle (CII), other teachers tested the trails and held a group discussion, followed by evaluation and revision. The last cycle (CIII) was similar to the second cycle, but the testers were students. Again, analysis and revision followed the testing. The outcomes of this cycle are the MCM tasks and trails to be used in the final project.

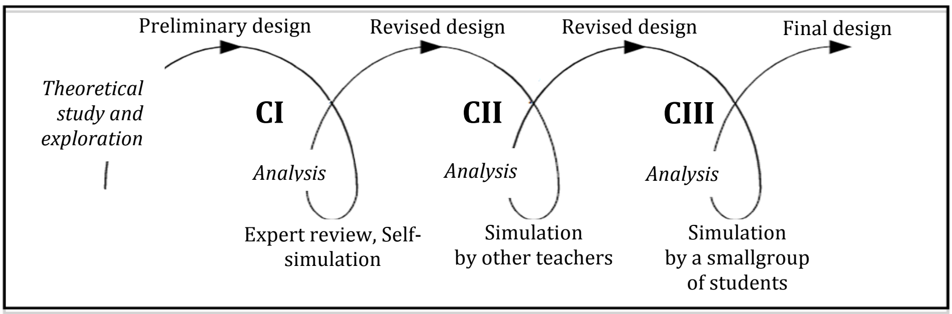

Figure 3. Design cycles within this study

Results and Discussion
A theoretical study was conducted to develop a theory of the MCM-Tasks.

What are the MCM-Tasks?
In The MathCityMap-Project, students experience mathematics through communication, connections, reasoning, and problem solving. The project fits into informal education and the popularisation of mathematics through out-of-school activities. The outdoor task should be authentic, i.e., connected to real life objects, and the results must be verifiable. The problems can be almost anywhere, and forming an idea for an authentic task can be achieved by sharpening the mathematical view. The MCM-Task should be in a real place, and the relevant information should only be obtainable on-site, so that the problem is solved there, not in the classroom.

The tasks in an area are connected to form a route with mathematics problems of various levels and types. Walking distance, walking time, difficulties, solving time, and the number of tasks affect the length of a route. Each route contains six to eight tasks and takes about 15 minutes to complete one task. Tasks are solved in cooperation, not competition.

The tasks bring attention to the processes of formulating and solving problems. Each question requires only a short answer, and three to five hints are provided on demand. The hints are framed as questions that meet the criteria of 'good questions.' Thus, they guide students to solve the problems by themselves, without giving the solution directly.

The project should be fun and challenging for both the task creator and the solvers. Its shows the importance of the task, trains behaviour to extract the relevant information and use basic algorithms for solving problems, challenges the students, and encourages them to enjoy learning mathematics.

Collaboration with eight secondary schools

The MathCityMap-Project needs organisation and planning, including support work alongside the creation of tasks and routes. In the pilot study, the project was organised by a team. Team work is fun, and multiple perspectives contribute to stronger outcomes. The project is to be carried out in collaboration with eight secondary schools in Semarang.

The exploration phase consisted of benchmarking, need analysis, and discussion. In May 2014, a discussion was held among mathematics teachers at the participating schools, four experts from the Mathematics and Computer Science Education, and students. The discussion topic was MCM task design considering teaching experiences and cross-checked with theoretical reviews.

The participating schools represent three school levels (high, medium, and low) and two locations (downtown and uptown). They were considered suitable for The MathCityMap-Project based on their characteristics and locations. Furthermore, teachers attended a meeting at the beginning of the project development. They were introduced to the project concept, and they discussed the gaps and problems in theory and practice, needs and conditions, social influence and constraints, and Indonesian school characteristics.

The project is prepared for the second semester (even semester) of 7^{th} and 8^{th} grade of secondary school during the dry season in Indonesia. To avoid traffic, the routes arelocated around the school district area or in areas that are easily and safely accessible. After school, students will follow the math trails in groups to complete the tasks on-site. Several issues have to be considered: e.g., that much of the subject matter has to be learned during school hours, limitations of device ownership, and prohibition on bringing mobile phones during school hours was inevitable.

The results of the theoretical study of the MCM tasks in the exploration phase were used as a basis for designing the MCM-Tasks in the next phase.

Design of the MCM-tasks

Tasks were designed at five locations in Semarang: Kota Lama, Taman KB, Kawasan Tugu Muda, Masjid Agung Jawa Tengah, and Kampus Unnes. At each location, six to eight tasks were connected in a route. They were reviewed by experts and will be used in The MathCityMap-Project and as examples in the MCM-Training for teachers.

MCM-training for teachers was conducted to implement the project in accordance with the concept and goal. The first part of the training was held in September 2014. The teachers attended lectures about the project's concept, how to design MCM-Tasks, how to use the MCM-Portal and MCM-App, and MCM-Task characteristics. They also tested the five routes that were created in the first step of the design phase. Next, they had one week to create MCM-Tasks around their schools. Two weeks later, in the second part of the training, they presented their MCM-Task designs and routes and received feedback from others. The result was the preliminary design of the MCM-Tasks.

In the first cycle of the design phase, after the review by experts, the participants carried out their own math trail and completed their own MCM-Tasks, then evaluated and revised them based on the simulation results. In the second cycle, other participants tested the tasks, and the creators revised them again based on the results and feedback. The last cycle was similar to the second cycle, but the testers were students. Finally, the MCM-Tasks were created in eight school district areas, with six to eight tasks within each area combined into a route. Tasks will be added, revised, and changed the next time with the same steps.

Figure 4(a) shows an example route, 'Rute Kota Lama' or 'The Old Town Route', which consists of six tasks. Three schools can implement TheMathCityMap-Project in this area. When the walking distance, walking time, difficulties, solving time, number of tasks, and other aspects were considered, this route was judged appropriate for use in The MathCityMap-Project.

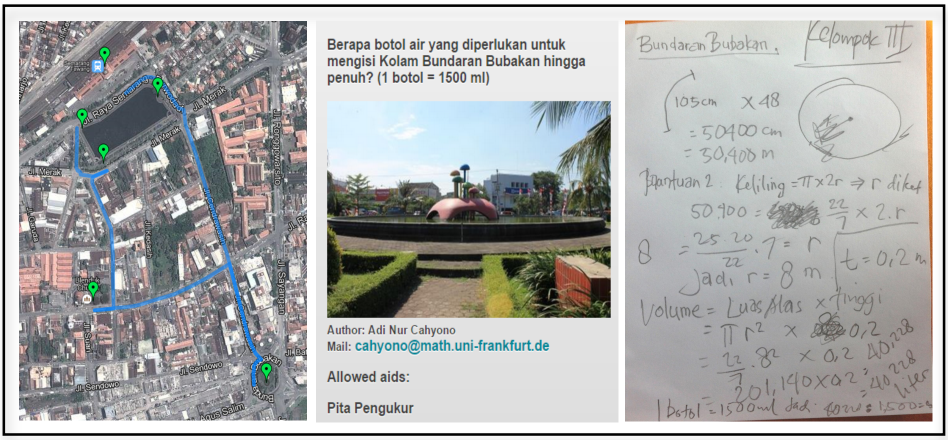

Figure 4.(a) 'Old Town Route'; (b) 'Bubakan Roundabout Task';
© A solution by a student in the simulation step

One task in this route is ‘Bubakan Roundabout’ or ‘Bundaran Bubakan’ (Figure 4(b)), which asks about the volume of a cylinder: ‘How many bottles of water are needed to fill the pond?’ After solving the task, students move on to the next task on the trail. If they have difficulties, they can use up to five hints (e.g., ‘Find the diameter of the pool surface using the relationship between the formula of the circumference and the surface area of a circle, because it is difficult to measure the diameter directly’). Figure 4(c) is a solution given by a student in the simulation step. It shows that students can solve the problem correctly using the available information and apply the hints.

Sharpness of mathematical view is one of the problems in the task design process. Teachers need practice to create good MCM-Tasks. In the simulation, the testers were able to solve some tasks without being on-site, because the relevant information could be found in the picture, or the objects used to solve the tasks had standard sizes (e.g., floor tiles, roof tiles, or a water storage tube).

In the small group of students simulation, the students walked along a route, discussing the tasks together. They enjoyed learning mathematics in a recreational atmosphere outside the classroom. Although they found some problems challenging, they did not despair because they knew there were hints on demand, so that they further enjoyed the activity.

However, some tasks need to be revised because they were less attractive to students in terms of their object, location, or mathematical concepts, and some editorial tasks need to be presented. Also, several routes were quite tiring for the students, so the number of tasks should be reduced. One task was not safe because of its location on a main street; this task should be given as a special task for Sundays, when the location becomes a car-free-day (CFD) area.

Moreover, some of the hints were improved. For example, ‘Determine the length of a segment from the side of the pond then multiply by the number of side segments of the pond’ was changed to ‘Is there a part of the pond that can be used to determine the circumference of the pond?’ The latter is better than the former because it challenges students to think for themselves instead of just following directions.

Summary

MCM-Tasks should be authentic tasks, connected to real life objects, and verifiable. The tasks in an area are combined into a route with a variety of mathematics problems. The project should be fun and challenging for both the task creator and the solvers.

The tasks are designed based on theoretical studies and adjusted to the needs and conditions of mathematics education in Indonesia. The cycle process within this study (creation-review-simulation-evaluation-revision) is important to improve the quality of tasks. Through this process, the final MCM-Tasks were created for use in The MathCityMap-Project in Indonesia.

The next question is, *‘How can The MathCityMap-Project for Indonesia be a part of the mathematics teaching and learning activities in Indonesian secondary schools to promote students’ motivations and teachers’ mathematical beliefs?’* This question will be considered in a future study.

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