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# Examining motivation in mobile app-supported math trail environments

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*The MathCityMap-Project was developed by combining the concept of a math trail program with advanced mobile technology. It aims at providing a new approach to promote student motivation to engage in meaningful mathematical activity. An explorative study was conducted as a pilot using nine secondary schools in the city of Semarang, in Indonesia, and 272 students and nine teachers were included. Using self-determination theory as a framework, we explored the motivation of students to engage in mobile app-supported math trail activity. Data collection procedures comprised observation, interviews, questionnaires, and student work analyses. Findings indicate that intrinsic motivation and identified regulation established an essential part of students' motivation to engage in this activity. The design of the learning environment, the use of mobile app, and the value of the mathematical task have contributed to this result.*

*Keywords: MathCityMap, mobile app, math trail, student motivation.*

## Introduction

A math trail, a path for discovering mathematics, was created as a medium for experiencing mathematics in all its characteristics, namely, communication, connections, reasoning, and problem solving (Shoaf, Pollak, & Schneider, 2004). In such a trail, students can simultaneously solve mathematical problems encountered along the path, make connections, communicate ideas and discuss them with their teammates, and use their reasoning and problem-solving skills. Although the math trail project is not new, supporting this outdoor education with mobile technology is an innovative approach to the program. This idea appears together with the fact that, in recent years, mobile technology has significantly improved and mobile phone use has significantly increased (Lankshear & Knobel, 2006). These advancements have been followed by the creation of many mobile phone applications (apps), including those intended for use in outdoor activities. In learning activities, Wijers, Jonker, and Drijvers (2010) suggested that mobile devices could be employed to facilitate learning outside the classroom. They also suggested that mobile technology could be exploited to support the outdoor educational program. Integrating advanced technology with the math trail program is the basis for the development of our project, called the MathCityMap-Project, in which math trails are facilitated by the use of GPS-enabled mobile phone technology. This project has been developed and implemented in Indonesia since 2013 and has been tailored to this country's situation. The main focus of this paper is to explore the motivation of students to engage in a math trail program supported by the use of a mobile app.

## Theoretical background

The MathCityMap-Project is a project of the math trail program, which is supported by the use of a GPS-enabled mobile phone app and uses specialized mathematical outdoor tasks (Jesberg & Ludwig, 2012). This project was not conceived merely to design and/or use the math trails. Instead, it includes the entire process: preparation (how to design it), implementation (how it runs), and evaluation (how

it impacts student motivation). The mobile phone app, as a supporting tool, was also created and used during this project. Therefore, the theoretical framework for the MathCityMap-Project study is underpinned by the concept of the math trail program, the use of mobile technology in mathematics education, and student motivation in mathematics.

A math trail is a walk in which mathematics is explored in the environment by following a planned route and solving mathematical outdoor tasks related to what is encountered along the path (English, Humble, & Barnes, 2010). In math trail activities, "children use mathematics concepts they learned in the classroom and discover the varied uses of mathematics in everyday life" (Richardson, 2004, p. 8). They discover real problems related to mathematics in the environment and also gain experience connecting mathematics with other subjects. Among the many benefits of a math trail (Richardson, 2004) is the creation of an atmosphere of adventure and exploration resulting from the fact that it is located outside the classroom. A math trail guide, such as math trail map or human guide, must be prepared to inform walkers about the math trail task stops and to show the problems that exist at each location. It also tells about the tools needed to solve the problems, so that the walkers are prepared before starting to walk on a trail. With the rapid development of technology nowadays, it is possible to collect the tasks and design a math trail guide based on a digital map and database.

In recent years, rapid developments in technology have occurred in the scope, uses, and convergence of mobile devices (Lankshear & Knobel, 2006). These devices are used for computing, communications, and information. Mobile devices are portable and, usually, easily connected to the Internet from almost anywhere. This makes them ideal for storing reference materials and learning experiences, and they can be general-use tools for fieldwork (Tuomi & Multisilta, 2010). Their portability and wireless nature allow them to extend the learning environment beyond the classroom into authentic and appropriate contexts (Naismith, Lonsdale, Vavoula, & Sharples, 2004). Wireless technology provides the opportunity for expansion beyond the classroom and extends the duration of the school day so that teachers can gain flexibility in how they use precious classroom activities. The use of mobile devices can also promote positive emotions for students toward learning mathematics (Daher, 2011). These advantages have been exploited through the MathCityMap-Project. Math trail blazers can create and upload math trails into a database through a web portal, then the math trail walkers can access them and complete the math trail with the help of a GPS-enabled mobile app (Cahyono & Ludwig, 2014; Jesberg & Ludwig, 2012).

In this paper, we focus on the exploration of the factors that motivate students to engage in mobile app-supported math trail activity. The academic literature distinguishes between two motivational concepts namely: extrinsic motivation and intrinsic motivation. An influential theory that explicates intrinsic–extrinsic motivation in depth is self-determination theory (SDT, Deci & Ryan, 1985). The SDT model conceptualizes a range of regulation from intrinsic motivation to amotivation. Between these, there exist identified regulation and external regulation. Intrinsic motivation exists when a student is engaged in an activity for his/her own sake/pleasure/satisfaction. Identified regulation refers to engagement that is valued as being chosen by oneself. External regulation is the type of motivation when engagement is regulated by rewards or as a way to avoid negative consequences. Lastly, amotivation is associated with engagement that is neither intrinsically nor extrinsically motivated (Guay, Vallerand, & Blanchard, 2000).

Having outlined the theoretical background for this study, we can clarify the research question: *what is the nature of student motivation to engage in a math trail program supported by the use of a mobile app?*

## Methods

An explorative study was conducted in the city of Semarang in Indonesia involving nine secondary schools. The participating schools represent three levels (high, medium, and low) and two location types (downtown and suburban). This study is a part of development research on the MathCityMap-Project for Indonesia. There were two main phases in this research, namely the design phase and the field experimentation phase. Here, we focused on studying student motivation to engage in the activity that was conducted in the second phase. This phase consisted of an introduction session, a treatment (math trails guided by the app), and a debriefing session. Student motivation was measured using the self-reported Situational Motivation Scale (SIMS) developed and validated by Guay, Vallerand, and Blanchard (2000) based on self-determination theory (SDT). The results of their study exposed that the SIMS represents a brief and adaptable self-report measure of situational intrinsic motivation, identified regulation, external regulation, and amotivation. ‘Situational motivation’ refers to the motivation individuals experience when they are currently engaging in an activity (Guay, Vallerand, and Blanchard, 2000). Therefore, this questionnaire is appropriate to be employed in this project to explore motivation of student to engage in the activity.

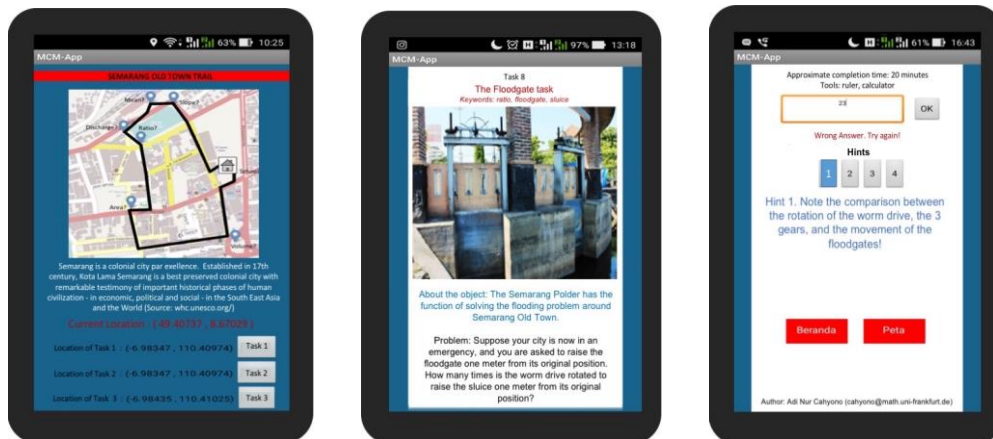
The SIMS is a 16-item questionnaire consisting of 4 subscales, intrinsic motivation (IM), identified regulation (IR), external regulation (ER), and amotivation (AM). In the first part of the instrument, the questionnaire asks, ‘Why are you currently engaged in this activity?’. Respondents are to rate a number of answers using a 7-point Likert scale from 1 (*not at all in agreement*) to 7 (*completely in agreement*) for each item. The items are ‘because I think that this activity is interesting’ (IM), ‘I am doing it for my own good’ (IR), ‘because I am supposed to do it’ (ER), ‘there may be good reasons to do this activity, but personally, I don’t see any’ (AM), ‘because I think this activity is pleasant’ (IM), ‘because I think this activity is good for me’ (IR), ‘because it is something that I have to do’ (ER), ‘I do this activity, but I am not sure if it is worth it’ (AM), ‘because this activity is fun’ (IM), ‘it was my personal decision’ (IR), ‘because I don’t have any choice’ (ER), ‘I don’t know; I don’t see what this activity brings me’ (AM), ‘because I feel good when doing this activity’ (IM), ‘because I believe that this activity is important for me’ (IR), ‘because I feel I have to do it’ (ER), and ‘I do this activity, but I am not sure it is a good thing to pursue it’ (AM).

The four subscale scores are then used to calculate a single motivation score called the Self-Determination Index (SDI) for each student using the following formula:  $SDI = (2 \times IM) + IR - ER - (2 \times AM)$  (Sinelnikov, Hastie, & Prusak, 2007). The SDI score ranges between  $(2 \times 1) + 1 - 7 - (2 \times 7) = -18$  and  $(2 \times 7) + 7 - 1 - (2 \times 1) = 18$ . A higher SDI score indicates the student is more self-determined and more intrinsically motivated to engage in the activity. A positive SDI score indicates that, overall, more self-determined forms of motivational type (IM & IR) are predominant (Vallerand & Ratelle, 2002). Then, open-ended follow-up questions were given to students to deepen the information about deciding factors affecting student engagement in this mathematical activity. Data were analyzed using qualitative methods to discover whether and what kind of motivations influenced these students. Quantitative data were also collected and analyzed. Non-parametric statistical

calculations were performed because the data consisted of ordinal scores, and normality could not be assumed.

## Results and discussion

In the first phase of the MathCityMap-Project study in Indonesia, technical implementation of the project was formulated, and a mobile app was also created to support the program (Cahyono & Ludwig, 2014). Thirteen math trails containing 87 mathematical outdoor tasks were also designed around the city of Semarang (Cahyono, Ludwig, & Marée, 2015). Task authors found mathematical problems that involved objects or situations at particular places around the city. They then created tasks related to the problems and uploaded them to a portal ([www.mathcitymap.eu](http://www.mathcitymap.eu)). In this portal, the tasks were also pinned on a digital map and were saved in the database. Each task contained a question, brief information about the object, the tools needed to solve the problem, hint(s) if needed, and feedback on answers given. Math trail routes can be designed by connecting a few tasks (6-8) in consideration of the topic, level, or location. In designing the trails, it is also necessary to consider several factors such as: safety, comfort, duration, distance, and accessibility for teachers who would observe and supervise all student activity.



**Figure 1: App interfaces (Map: ©OpenStreetMap contributors)**

Figure 1 shows examples of the app's interfaces including an example route, task, feedback, and hint. Math trail routes can be accessed by students via the mobile app, a native app that was created by the research team as part of this project. Installation of a file in \*.apk format was uploaded to the portal as well as the Google PlayStore™. From there, students could download and install the app, which works offline and runs on the Android mobile phone platform. Students can then carry out math trail activities with the help of the app. They follow a planned route, discover task locations, and answer task questions related to their encounters at site, then move on to subsequent tasks. The app informs them of the tools needed to solve the problems, the approximate length of the trail, and the estimated duration of the journey. On the trail, the app, supported by GPS coordinates, aids the users in finding the locations. Once on site, users can access the task, enter the answer, get the feedback, and ask for hints if needed.

In the second phase, field experiments were conducted with 272 students and nine mathematics teachers. Each school was represented by a class consisting of an average of 30 students. They were divided into groups of five to six members. Four schools carried out activities outside the school while five schools conducted activities in the school area. These choices were made because of

conditions and situations (such as: safety and availability of teaching and learning time) unique to each school. The activities were conducted during normal school hours over two 45-minute periods beginning with the teachers giving a brief explanation of the learning activities and goals. Groups then began their journeys, each from a task location that was different from the others (Group I started at task I, Group II from task II, and so on). As the groups trekked the trail, teachers observed and supervised student activities but were not expected to provide assistance because all the necessary information was to be provided by the app. Once the activity was completed or maximum time allowed for the activity had passed, the students moved to the next task. After completing the trail, each group returned to class, then had a discussion with the teacher about the task solutions and what they learned along the trail. At this time the questionnaire was also completed by the students. All 272 students' SIMS responses and SDI scores are summarized in Table 1.

	IM	IR	ER	AM	SDI
N	272	272	272	272	272
MIN	3.50	2.25	1.00	1.00	2.00
MAX	7.00	7.00	6.25	5.50	16.25
AVERAGE	5.9770	4.7215	3.4651	2.9779	7.3180
SD	0.82939	1.23314	0.93080	0.91471	2.92629

**Table 1: Students' SIMS and SDI scores**

Averages SIMS scores for the four subscales varied considerably, ranging from 1.00 to 7.00. The standard deviations indicated adequate variability in all subscales. It is apparent that the nature of these students' motivations to engage in the activity is diverse. However, all had positive SDI scores (ranging from MIN = 2.00 to MAX = 16.25 and average  $\pm$  SD = 7.3180  $\pm$  2.92629). This result indicates that overall, their motivation was more self-determined. Positive scores in this case indicate that internalized forms of motivation, namely intrinsic motivation and identified regulation, were predominant. Students perceived the activity to be interesting or enjoyable (an indicator of IM) and meaningful or valuable (an indicator of IR). They were engaged in the activities for their own sakes/pleasure/satisfaction, and their engagement was considered to be a self-choice. This finding is supported by the Independent-Samples Kruskal-Wallis Test (Table 2), which shows that there was a statistically significant difference in score between the SIMS subscales,  $\chi^2(2) = 623.583$ ,  $p = 0.000$ , with a mean rank score of 886.37 for IM, 637.52 for IR, 379.97 for ER and 274.15 for AM.

Compared with others subscales scores (Table 1), the amotivation subscale had low average SIMS scores ( $AM_{\text{average}} = 2.9779 \pm 0.91471$ ), which were contributing factors to the positive SDI scores. These low scores indicate that students enjoyed the activity and found value in it, which was reflected in the intrinsic motivation scores ( $IM_{\text{average}} = 5.9770 \pm 0.82939$ ) and identified regulation scores ( $IR_{\text{average}} = 4.7215 \pm 1.23314$ ). Students also reported being motivated by and were reacting to external demand, an indicator of extrinsic regulation. However, the ER scores ( $ER_{\text{average}} = 3.4651 \pm 0.93080$ ) show they tended to be neutral on this subscale.

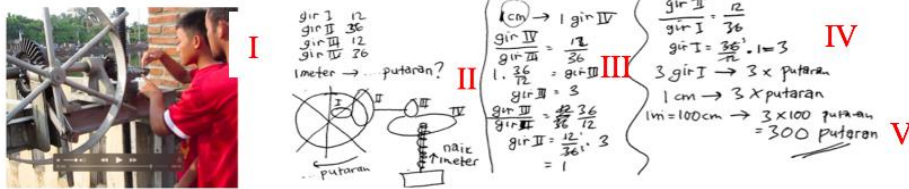
	Subscale	N	Mean Rank
Score	IM	272	886.37
	IR	272	637.52
	ER	272	379.97
	AM	272	274.15

	Score
Chi-Square	623.583
df	3
Asymp. Sig.	.000

**Table 2: Kruskal-Wallis Test using subscale (IM, IR, ER, AM) as the grouping variable.**

The open-ended questions asked in the next step focused on two types of motivation, namely intrinsic motivation and identified regulation. The first question was, ‘*Why did you enjoy the activity?*’ We found that 30% of the students enjoyed learning outside the classroom, 23% were excited to use the advanced technology, 18% were satisfied with applying mathematics, 16% liked collaborating, 11% reported different reasons, 2% mentioned negative feelings, and 0% did not give a reason. The second question was ‘*What experiences influenced your consideration that this activity was valuable?*’ (each student could mention more than one experience). Students mentioned application of mathematics in real life 158 times, outdoor mathematical activities 96 times, advanced technology for math 87 times, use of non-standard measuring tools 79 times, team work 72 times, activities in public places 65 times, and other 19 times. These answers showed that most students were delighted to engage in this activity because it was conducted outside the classroom, an unusual setting that offered comfortable conditions and it was a free and fun activity. The use of mobile devices for outdoor mathematics learning activities has become an attraction, encouraging students to engage in this activity. However, as a serious mathematical learning activity, it was not only enjoyable, but the students considered it a valuable activity. They reported that through this activity they learned how to apply mathematics in the real world, even where they had never thought about it in the past. The use of the latest technology in the learning process has also been reported as a valuable experience and new knowledge for them.

The self-reported data and answers to the follow-up questions were cross-checked with information obtained through field observations and the student works analyses. For example, here is one of the results of observations and analysis of student work on the Flood Gate Task, a task located on the Old Town Route. In this task, the problem statement is, ‘*Suppose your city is now in an emergency, and you are asked to raise the floodgate one meter from its original position. How many times must the worm drive be rotated to raise the sluice one meter from its original position?*’. This task is situated at one of the tourist attractions, an icon of the city, namely the Old Town area of Semarang City. All students agreed this was a pleasant place for learning math, and it was near the school where there were lots of trees, a pond, a garden, nice old buildings, and traffic was not too congested. These conditions made them feel joyful and comfortable in performing the activity there. Not only the location was exciting for them, the task was also considered by students to be a meaningful mathematical task because it was an important issue for them as citizens to know how this floodgate works. In this way, they could save their town if there were an impending disaster. Figure 2 shows an example of students working on this task.



**Figure 2: Students work on the flood gate task**

It appears that the students had the opportunity to learn and practice ways of solving real problems by following the stages of mathematizing, namely, understanding a problem situated in reality (I), organizing the real-world problem according to mathematical concepts and identifying relevant mathematics (II), transforming the real-world problem into a mathematical problem that represents the problem situation (III), solving the mathematical problem (IV), and interpreting the mathematical solution in terms of the real situation (V). In addition, working in the environment to find the hidden task location was interesting and challenging for the students. They reported that the more hidden the task location, the more curious they were to find it. It was breathtaking for them when they had to match the coordinates of their current position and the coordinates of the task location. Here, students recognized the importance and attractiveness of utilizing a GPS-based mobile app as a navigation tool in the math trail activity. This is just one example task, and in general, the students' activities in this field experiment were similar. This explanation proves that the results of the student self-report instrument to determine their motivation to engage in activities coincided with actual conditions in the field.

Based on these findings, we conclude that the design and arrangement of the math trail and the mobile app as well as a combination of both have been successful in creating a pleasant situation and attractive environment offering valuable knowledge and experience in mathematics. They embody the aspects of enjoying or being interested in the activity and the use of advanced mobile technology for learning mathematics (an indicator of intrinsic motivation) and of value and meaningfulness of the mathematical tasks and the activity (an indicator of identified regulation), which were generated through the implementation of this project.

## Conclusions

In conclusion, our findings indicate that student motivation to engage in the math trails program supported by the use of a mobile app was complex. Both intrinsic and extrinsic types of motivation, as well as amotivation, were found in the reasons for completing the activity. However, we also found that students reported and demonstrated more intrinsically motivating rather than extrinsically motivating and amotivating factors for engaging in the activity. While intrinsic motivation was an essential part, identified regulation was also important. The design of the project and its technical implementation contributed to these results, as reported by the student through the self-report instrument, and it was demonstrated through their activities and work. Therefore, in the implementation of the MathCityMap-Project, we must be aware of the important role of influencing student motivation when designing a mobile app-supported math trail activity. The relevance and value of the task must be clearly identified and linked to the objective of the project. Most importantly, students must enjoy and be attracted to the activity, both in completing the math trail task and in using the mobile app. These are the main factors that need to be considered when implementing the MathCityMap-Project.



## References

- Cahyono, A. N., & Ludwig, M. (2014). Designing of The MathCityMap-Project for Indonesia. In S. Oesterle, C. Nicol, P. Liljedahl, & D. Allan (Ed.). *Proceedings of the 38th Conference of the International Group for the Psychology of Mathematics Education and the 36th Conference of the North American Chapter of the Psychology of Mathematics Education Vol 6* (pp. 33). Vancouver: PME.
- Cahyono, A. N., Ludwig, M., & Marée, S. (2015). Designing mathematical outdoor tasks for the implementation of The MCM-Project in Indonesia. In C. Visto Yu (Ed.). *EARCOME 7. In pursuit of quality Mathematics education for all: Proceeding of the 7th ICMI-East Asia Regional Conference on Mathematics Education* (pp.151-158). Quezon City: EARCOME.
- Daher, W. (2011). Building Mathematics Cellular Phone Learning Communities. *International Journal of Interactive Mobile Technologies*, 5(2), 9-16.
- Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum Press.
- English, L. D., Humble, S., & Barnes, V. E. (2010). Trailblazers. *Teaching children mathematics*, 16(7), 402-409.
- Guay, F., Vallerand, R., & Blanchard, C. (2000). On the Assessment of Situational Intrinsic and Extrinsic Motivation: The Situational Motivation Scale (SIMS). *Motivation and Emotion*, 24(3), 175-213.
- Jesberg, J., & Ludwig, M. (2012). MathCityMap-Make Mathematical Experiences in out-of-School activities using mobile technology. *The Proceedings of the 12th International Congress on Mathematical Education* (pp. 1024-1031). Seoul: ICME.
- Lankshear, C., & Knobel, M. (2006). *New literacies: Everyday literacies and classroom learning*. Maidenhead and New York: Peter Lang.
- Naismith, L., Lonsdale, P., Vavoula, G., & Sharples, M. (2004). *Literature Review in Mobile Technologies and Learning (Futurelab Series Report 11)*. Bristol: Futurelab.
- Richardson, K. M. (2004). Designing Math Trails for the Elementary School. *Teaching Children Mathematics*, 11(1), 8-14.
- Shoaf, M. M., Pollak, H., & Schneider, J. (2004). *Math trails*. Lexington, MA: The Consortium for Mathematics and its Applications (COMAP).
- Sinelnikov, O. A., Hastie, P. A., & Prusak, K. A. (2007). Situational Motivation during Seasons of Sport Education. *The International Council for Health, Physical Education, Recreation, Sport and Dance Journal of Research*, 2(1), 43-47.
- Tuomi, P., & Multisilta, J. (2010). MoViE: Experiences and attitudes—Learning with a mobile social video application. *Digital Culture & Education*, 2(2), 165-189.
- Vallerand, R. J., & Ratelle, C. F. (2002). Intrinsic and extrinsic motivation: A hierarchical model. In E. L. Deci, & R. M. Ryan (Eds.), *Handbook of self-determination research* (pp. 37-63). Rochester: The University of Rochester Press.
- Wijers, M., Jonker, V., & Drijvers, P. (2010). MobileMath: Exploring mathematics outside the classroom. *ZDM Mathematics Education*, 42, 789–799.