This is a preprint of the following chapter: Hartmann LM., Schukajlow S. (2021) Interest and emotions while solving real-world problem inside and outside the classroom. In: Leung F.K.S., Stillman G.A., Kaiser G., Wong K.L. (eds) Mathematical Modelling Education in East and West. International Perspectives on the Teaching and Learning of Mathematical Modelling. Springer, Cham reproduced with permission of Springer. The final authenticated version is available online at: https://doi.org/10.1007/978-3-030-66996-6_13.

Interest and emotions while solving real-world problems inside and outside the classroom

Luisa-Marie Hartmann and Stanislaw Schukajlow

Abstract Solving real-world (or modelling) problems outside the classroom can link students' real lives with mathematics on the basis of an authentic experience with the subject matter. This may trigger students' interest and positive emotions and diminish their negative emotions. However, no empirical studies have compared students' interest and emotions while they solved real-world problems inside and outside the classroom. We examined whether students are more interested in and feel more enjoyment and less boredom while solving real-world problems outside than inside the classroom. To answer these research questions, students ($N = 43$) were randomly assigned to two groups, an outside group and an inside group. Our results indicate that it is not the location but the type of problem that is important for the development of students' interest and emotions.

1 Introduction

Interest and emotions are important for students' learning. However, students tend to feel more boredom than enjoyment in mathematic classes (Goetz & Hall 2014), they are often not interested in mathematics, and their interest in mathematics even tends to decrease from grades 5 to 10 (Pekrun et al. 2007). What are possible reasons for these findings? Although mathematics is a part of our everyday lives (Niss 1994) and mathematical knowledge fosters the understanding and development of aspects of diverse extra-mathematical areas (e.g., medicine, pharmacy, architecture, security of online banking, or email encryption), students often do not recognise the connection between mathematics and reality. They perceive real-world problems in their lessons as artificial and do not link their everyday or future lives to the contents of mathematics lessons. As a result, students might be not interested in mathematics and might thus feel bored in or fail to enjoy their mathematic classes. In order to strengthen the connection between the real world and mathematics, school tasks sometimes include photographs of real-world objects or videos of real-world situations. However, the typical mathematic class takes place inside the classroom. Given that no one said that mathematics classes must take place inside the classroom, we hypothesised that solving real-world problems outside the classroom as offered by a math trail might motivate students more than solving the same problems inside their regular classrooms. Following these considerations, we aimed to investigate the effects of this teaching method on students' interest and emotions.

2 Theoretical Background

2.1 Interest, enjoyment, and boredom

Interest describes a relationship of a person (e.g., a student) and an object or activity (e.g., solving a mathematical problem) (Hidi & Renninger 2006). Theories of interest have distinguished between situational and individual interest. If the student enjoys solving the problem and values the problem, he or she will experience high situational interest. This type of interest can be triggered by environmental stimuli and can fluctuate from moment to moment (interest as a 'state') (Hidi & Renninger 2006). However, if this situational interest is maintained over time, it can change into individual interest (interest as a 'trait'). Students with a high level of individual interest look for mathematics in their environment, solve mathematical problems in their free time, and discuss mathematical problems with other people (Schukajlow et al. 2017). In the present study, we focussed on task-specific interest (i.e., situational interest) because of its importance for the early stage of interest development. According to the theory of interest, learning environments that provide meaningful activities that have personal significance can trigger students' interest (Hidi & Renninger 2006). Therefore, offering reality-related problems within an authentic learning environment can improve students' situational interest.

The construct of interest and the construct of emotions are closely related to each other. Emotions can be described as a complex, multi-dimensional construct that comprises motivational, expressive, physiological, and cognitive parts (Pekrun 2006). In the present study, we focussed on the emotions of enjoyment and boredom because these emotions are two of the most frequently reported emotions in the context of learning (Pekrun et al. 2002). According to the *control-value theory of achievement emotions*, an emotion can be activating or deactivating and have a positive or negative valence. For example, enjoyment is a positive-activating emotion. If students enjoy a situation, they will want to continue task processing and will feel happy. Boredom is a negative-deactivating emotion. If students are bored, they will not want to continue task processing and will not like the situation (Pekrun 2006). In the *control-value theory of achievement emotions*, enjoyment occurs with high control appraisals (e.g., high perceived competence in solving a problem) and high value appraisals (e.g., the perceived importance of a learning activity) (Pekrun 2006). Boredom occurs with too high or too low control appraisals and low value appraisals (Pekrun 2006). Control appraisals are too high, for example, if the presented task is too easy for the student, and they are too low, for example, if the presented task is too difficult. Value appraisals are low, for example, if students do not consider task processing to be important for them. Solving real-world problems in an authentic learning environment can improve students' perceived value and thereby affect their enjoyment and boredom.

2.2 Real-world problems in the context of a math trail

Real-world (or modelling) problems require demanding transfer processes between reality and mathematics. Students begin to solve real-world problems by constructing a model of the situation in the real world. Then they translate this model into a mathematical model and switch from the real world to the mathematical world. After that, calculations can be made in the mathematical world, and the mathematical results have to be interpreted and validated with respect to reality.

Real-world problems are usually complex, open-ended, and authentic (Maaß 2006). The authenticity of a problem can be determined by the presented context or the learning environment. The present study focusses on authentic learning environments because increasing authenticity can strengthen the relation of a problem to the real world (Vos 2015).

An example of a real-world problem is *The Climbing Frame* task.

The Climbing Frame

How many metres of rope does the climbing frame consist of?

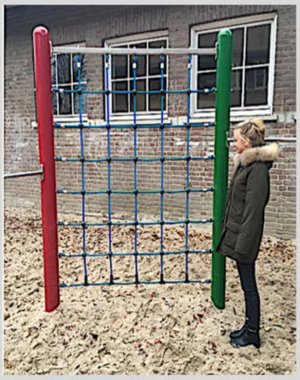

Fig. 1.1 The real-world problem *The Climbing Frame*

In Fig. 1.1, we present a real-world problem that can be offered students in the classroom. To solve a problem with missing information (also called a Fermi-Problem), students must notice the missing information and make realistic assumptions, including identifying and supplementing the missing quantities (Krawitz et al. 2018). Photographs or videos can be helpful for estimating the missing information and can make the relation between the problem and the real world more obvious. However, real-world problems can be offered not only in the classroom but also outside. Kleine et al. (2012) suggested that working on real-world problems outside the classroom is more motivating than working with photographs or videos in the classroom. A possible explanation could be that the learning environment outside offers an authentic experience with objects in students' environments, and students therefore perceive that the processing of the task is more valuable.

Prior research investigated real-world problems outside the classroom as part of a math trail. Math trails are out-of-classroom activities. In such a trail, students can solve mathematical problems that refer to real objects. Students discover these real problems in their environment as they follow a planned route (Cahyono & Ludwig 2017). This learning environment offers an authentic experience with the subject matter (Buchholtz & Armbrust 2018). Cahyono and Ludwig (2017) showed that students were interested in solving real-world problems along a math trail outside the classroom with the help of the MathCityMap-

App[1], and a study by Buchholtz and Armbrust (2018) revealed that students enjoyed solving real-world problems on a math trail outside the classroom. However, to the best of our knowledge, neither of these studies compared the effects of solving real-world problems inside versus outside the classroom on students' interest or emotions.

2.3 Research questions

To help close this research gap, we aimed to address the following research questions:

(1) Are students who solve real-world problems outside the classroom on a math trail more interested in solving these problems than students who solve the same real-world problems inside the classroom?
(2) Do students who solve real-world problems outside the classroom on a math trail feel more enjoyment and less boredom than students who solve the same real-world problems inside the classroom?

On the basis of the importance of the learning environment for triggering students' interest (Hidi & Renninger 2006) and results from empirical research by Cahyono and Ludwig (2017), we expected that students who solved the real-world problems outside the classroom on a math trail would be more interested in solving the problems than students who solved the same real-world problems inside the classroom. Concerning students' emotions and based on results from empirical research by Buchholtz and Armbrust (2018), we expected that students who solved the real-world problems outside the classroom on a math trail would feel more enjoyment and less boredom than students who solved the same real-world problems inside the classroom because solving problems outside a classroom might improve the value of task processing, which is important for enjoyment and boredom.

3 Methodology

3.1 Participants and Procedure

To answer these research questions, 50 sixth graders (74% female, 26% male, average age: 11.38 years (SD = 0.49)) from a German middle school took part in this study. The students had no prior experience in solving real-world problems with missing information. On the basis of pretest results, students from each class were randomly assigned to two groups with the same number of students in each group such that the average age, interest in mathematics, ratio of males and females, and average achievement level in mathematics did not differ. The students solved six problems that referred to their school environment in groups of four to five and were given 60 minutes to finish the tasks (10 minutes each). Afterwards, they completed a questionnaire about their task-specific interest, enjoyment, and boredom. The experimental group solved six real-world problems outside the classroom with the MathCityMap-App. The control group solved the same six real-world problems inside the classroom with photos or videos. The problems were presented to the experimental group in

[1] The MathCityMap-App is a project from the IDMI of the Goethe-University in Frankfurt. It provides the opportunity to develop interesting tasks concerning objects in reality and to solve them in the form of a math trail (Cahyono & Ludwig 2017).

the app, whereas the control group used print-outs that were left on tables. In addition, a photo of the object and a hint about the size of the object were located on each table in the classroom. The tables in the classroom were arranged in a learning circle. During task processing, students could fall back on three staged hints. The experimental group could access them in the app, whereas in the classrooms, they were presented on flash cards on the different tables. After task processing, the experimental group entered their result in the app and received direct feedback on its correctness. The students in the classroom compared their results with the result on a flash card. Both groups could then read one solution to the problem—the experimental group in the app and the control group on the flash cards.

3.2 Measures

To measure interest, enjoyment, and boredom, we used well-evaluated 5-point Likert scales ranging from 1 (not at all true) to 5 (completely true). Interest was measured with three self-developed items based on a well-evaluated scale used in prior studies (Frenzel et al. 2012) (see Table 1.1). The scale for task-specific interest achieved good reliability (*Cronbach's* $\alpha = .88$). To measure enjoyment and boredom, we used items from the well-evaluated Achievement Emotions Questionnaire (Pekrun et al. 2011). Each scale included three items (see Table 1.1). The Cronbach's alpha reliabilities were .88 for enjoyment and .69 for boredom.

Table 1.1 Items used to assess task-specific interest, enjoyment, and boredom

Scale	Item
Task-specific interest	Task processing was exciting.
	I am already curious about further tasks.
	I would like to work on such tasks more often.
Enjoyment	I enjoyed task processing.
	I was happy during task processing.
	Task processing was great fun for me.
Boredom	Task processing was boring.
	I got so bored during task processing that I had trouble remaining alert.
	I did not want to continue my work because it was so boring.

3.3 Data analysis

To test the results for significance, we used t-tests for independent samples. We excluded three students with missing values (two students from the experimental group and one student from the control group) and four students with outliers (two students from each group) to avoid distorting the results. Thus, the number of students was reduced to N = 21 in the experimental group and to N = 22 in the control group.

4 Results

4.1 Task-specific interest

We expected that students who solved the six real-world problems outside the classroom on a math trail would be more interested in the tasks than students who solved the same problems inside the classroom. Table 1.2 presents students' task-specific interest while solving real-world problems inside and outside the classroom.

Table 1.2 Values for students' task-specific interest

Location		Task-specific interest	
	N	*M*	*SD*
Outside (EG)	21	4.25	0.92
Inside (CG)	22	4.14	0.65

Both the experimental and control groups reported high task-specific interest. The statistical analysis revealed that contrary to our expectations, students experienced the same level of task-specific interest while solving the real-world problems inside and outside the classroom ($t(43) = 0.46$, $p = .646$) and that the location had only a small effect on students' task-specific interest ($d_{Cohen} = 0.138$).

4.2 Enjoyment and Boredom

For students' enjoyment and boredom, we expected that students who solved the real-world problems outside the classroom on a math trail would feel more enjoyment and less boredom than students who solved the same real-world problems inside the classroom. The descriptive statistics concerning students' enjoyment and boredom are presented in Table 1.3 and revealed a high level of enjoyment and low level of boredom in both groups.

Table 1.3 Values for students' enjoyment and boredom

Location		Enjoyment		Boredom	
	N	*M*	*SD*	*M*	*SD*
Outside (EG)	21	3.99	0.94	1.40	0.45
Inside (CG)	22	3.85	0.99	1.51	0.59

Contrary to our expectations, students' enjoyment during task processing did not differ between the experimental and control groups ($t(48) = 0.49$, $p = .627$) and the location had only a small effect on students' enjoyment ($d_{Cohen} = 0.145$). Students' boredom during task processing did not differ between the groups either ($t(47) = -0.67$, $p = .491$) and the location also had a small effect on students' boredom ($d_{Cohen} = 0.210$). Hence, students experienced the same level of enjoyment and boredom while solving real-world problems inside and outside the classroom.

5 Discussion

5.1 Task-specific interest

In this chapter, we aimed to analyse how solving real-world problems outside the classroom would affect students' task-specific interest. On the basis of theoretical considerations from interest theory (Hidi & Renninger 2006) and prior research that indicated that students are interested in solving real-world problems outside the classroom (Cahyono & Ludwig 2017), we expected that students would be more interested in solving real-world problems outside the classroom than inside. However, our analysis did not confirm this hypothesis. Students experienced the same level of task-specific interest no matter whether they worked on it inside or outside the classroom. One possible explanation for these results could be the similarity between the problems offered in the two groups. Because the problems in both groups referred to students' school environment, students may have perceived the problems inside the classroom as authentic problems.

5.2 Enjoyment and Boredom

Additionally, we aimed to analyse how solving real-world problems outside the classroom would affect students' enjoyment and boredom. On the basis of theoretical considerations from the *control-value theory of achievement emotions* (Pekrun 2006) and prior research that indicated that students enjoy solving real-world problems from a math trail outside the classroom (Buchholtz & Armbrust 2018), we expected that students who solved the problems outside the classroom would experience more enjoyment and less boredom than students who solved the problems inside the classroom. Contrary to our expectations, our analysis revealed that students experienced the same level of enjoyment and boredom while solving real-world problems inside and outside the classroom. Hence, our analysis did not confirm our hypothesis. One possible explanation for these results could be that due to the similarity of the problems, the two processing situations were accompanied by high control and value appraisals. Both processing situations might be accompanied by high control appraisals due to the staged hints and therefore the adaption of the tasks to students' competences. High value appraisals may have been enhanced by the authentic and realistic contexts and the significance of the problems for the students' lives and group work.

6 Strengths and Limitations

Our study has some important limitations. As we aimed to investigate the effects of working on real-world problems outside the classroom, we posed identical real-world problems with high levels of authenticity in the experimental and control groups. Therefore, task-specific interest and emotions may have been influenced by the newness of the problem type in both groups. Further, we asked for task-specific interest, enjoyment, and boredom on the posttest and not after every single task because we wanted to avoid interrupting the task processing. Moreover, the experimental group used digital technology, which can also influence students' interest and emotions. However, we do not think that the digital technology (MathCityMap-App) decreased the positive effects of working on the problems outside the classroom because in a prior study, digital technology was found to be the prevalent source of students' enjoyment of task processing (Cahyono & Ludwig 2017). In our study, students worked in small groups of four to five students because group work was found to be preferable for solving real-world problems (Schukajlow et al. 2012). However, the clustering effects could have affected our results because the students in each small group may have influenced each other's perceptions of their interest and emotions. Finally, due to the small sample size, our results have to be interpreted with caution.

7 Conclusion and Summary

Working on real-world problems as part of a math trail can give students the opportunity to perceive the connection between their world and mathematics. This can offer an authentic experience with the subject matter and might thereby trigger positive emotions and interest. As interest and emotions have a high impact on students' learning (Schukajlow et al. 2017), one of the main aims of mathematics classes should be to foster students' interest and positive emotions and to diminish their negative emotions. Therefore, the aim of this work was to examine whether students are more interested in and experience more enjoyment and less boredom while solving real-world problems outside the classroom than students who solve the problems inside the classroom.

Our findings can contribute to a better understanding of the role that authentic learning environments (e.g., outside the classroom) play in the context of solving real-world problems. Overall, our results indicate that students have high interest and experience high enjoyment and little boredom while solving real-world problems, whether the problems are solved outside on a math trail or inside the classroom. We conclude that it is not the learning environment outside the classroom or the technology but the type of problem that is important for the development of students' interest and emotions. We argue that teachers should more often pose problems that refer to students' authentic environments inside and outside the classroom.

References

Buchholtz N., & Armbrust A. (2018). Ein mathematischer Stadtspaziergang zum Satz des Pythagoras als außerschulische Lernumgebung im Mathematikunterricht. [A mathematical city walk to the Pythagorean Theorem as an extracurricular learning environment in mathematics teaching.] In S. Schukajlow & W. Blum (Eds.), *Evaluierte Lernumgebungen zum Modellieren. Realitätsbezüge im Mathematikunterricht* (pp. 143-163). Wiesbaden: Springer Spektrum.

Cahyono, A. N., & Ludwig, M (2017). Examining motivation in mobile app-supported math trail environments. In T. Dooley & G. Gueudet (Eds.), *Proceedings of the Tenth Congress of the European Society for Research in Mathematics Education (CERME10, February 1 – 5, 2017)* (pp. 2523-2530). Dublin, Ireland: DCU institute of Education and ERME.

Frenzel, A.C., Pekrun, R., Dicke, A.L., & Goetz. T. (2012). Beyond quantitative decline: Conceptual shifts in adolescents‘ development of interest in mathematics. *Development Psychology, 48*(4), 1069-1082.

Goetz, T., & Hall, N. C. (2014). Academic Boredom. In R. Pekrun & L. Linnenbrink-Garcia (Eds.), *International Handbook of Emotions in Education* (pp. 321-340). New York: Routledge.

Hidi, S., & Renninger, K.A. (2006). The Four-Phase Model of Interest Development. *Educational Psychologist, 41*(2), 111–127.

Kleine, M., Ludwig, M., & Schelldorfer, R. (2012). Mathematik draußen machen - Outdoor Mathematics. *Praxis der Mathematik, 47,* 2-8.

Krawitz, J., Schukajlow, S., & Van Dooren, W. (2018). Unrealistic responses to realistic problems with missing information: What are important barriers? *Educational Psychology, 38*, 1221-1238.

Maaß, K. (2006). What are modelling competencies? *ZDM, 38*(2), 113-142.

Niss, M. (1994). Mathematics in society. In R. Biehler, R.W. Scholz, R. Straesser & B. Winkelmann (Eds.), *Didactics of mathematics as a scientific discipline* (pp. 367-378). Dodrecht: Kluwer Academic Publisher.

Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Reviews, 18*(4), 315-341.

Pekrun, R., Goetz, T., Frenzel, A.C., Barchfeld, P., & Perry, R.P. (2011). Measuring emotions in students' learning and performance: The Achievement Emotions Questionnaire (AEQ). *Contemporary educational psychology, 36,* 26-48.

Pekrun, R., Goetz, T., Titz, W., & Perry, R. P. (2002). Academic Emotions in Students' Self-Regulated Learning and Achievement: A Program of Qualitative and Quantitative Research. *Educational Psychologist, 37*(2), 91–105.

Pekrun, R., vom Hofe, R., Blum, W., Frenzel, A. C., Götz, T., & Wartha, S. (2007). Development of mathematical competencies in adolescence: the PALMA longitudinal study. Studies on the Educational Quality of Schools: The Final Report on the DFG Priority Programme, 17–37.

Schukajlow, S., Leiss, D., Pekrun, R., Blum, W., Müller, M., & Messner, R. (2012). Teaching methods for modelling problems and students' task-specific enjoyment, value, interest and self-efficacy expectations. *Educational Studies in Mathematics, 79*(2), 215–237.

Schukajlow, S., Rakoczy, K., & Pekrun, R. (2017). Emotions and motivation in mathematics education: Theoretical considerations and empirical contributions. *ZDM – Mathematics Education, 49*(3), 307-322.

Vos, P. (2015). Authenticity in extra-curricular mathematics activities: Researching authenticity as a social construct. In G.A. Stillman, W. Blum & M.S. Biembengut (Eds.), *Mathematical Modelling in Education Research and Practice* (pp. 105-113). Cham: Springer.