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Preservice teachers' interest and self-efficacy beliefs while posing problems

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Problem posing is considered to have great potential to foster students' motivation because it provides the opportunity to create problems on the basis of individual interests and abilities. However, whether learners indeed use this opportunity is an open question. The aim of the present study was to investigate the role of interest and self-efficacy expectations in problem posing. In interviews, we asked preservice teachers (N = 7) why they decided to pose a certain problem, and we focused on their interest and self-efficacy expectations when we analyzed the data. The most important factor was preservice teachers' interest in the answer to the posed problem. Self-efficacy expectations have been also revealed as important for their decision to pose a certain problem. Preservice teachers wanted to be able to solve the problem or to master problem posing by posing multiple problems or a problem with adequate difficulty.

Keywords: Problem posing, interest, self-efficacy, real-world problems, preservice teachers.

Introduction

Problem posing has recently been receiving greater attention from the scientific community. Researchers have emphasized that problem posing has the potential to help students learn mathematics and may be particularly beneficial for students' motivation (Cai & Leikin, 2020). Problem posing conveys the experience of autonomy and control by allowing students to generate problems that fit their own interests, needs, and abilities. Consequently, learners' interest and self-efficacy expectations can be expected to be important for their problem posing processes. There is little research on the relationships between interest, self-efficacy, and problem posing, and prior studies have rarely addressed how interest and self-efficacy can influence the posing of problems. The present study is aimed at gaining a better understanding of the roles that interest and self-efficacy play for problem posing by investigating learners' beliefs about factors that affect the development of self-generated problems.

Theoretical background

Problem Posing

Problem posing is typically defined as the generation of new problems and the reformulation of given problems (Silver, 1994). It is considered a powerful learning approach for improving students' motivation and problem solving abilities and is also an important learning goal in itself (Cai et al., 2015). Even if some progress has been made in recent years, problem posing is still a rather young and evolving field in which scholars are just beginning to develop an understanding of the processes that take place and the benefits problem posing can have for the learning of mathematics. Here, we look at problem posing from the perspective of modelling and applications in mathematics education. We focus on modelling-related problem posing, which we define as the generation of real-world

questions that can be solved with the help of mathematics on the basis of stimuli that are connected to the real world (e.g., textual descriptions of real-world situations, pictures, or artefacts from the real world) (Hartmann et al., 2021). An example of problem-posing stimuli used for modelling-related problem posing is depicted in Figure 1.


<p>Cable Car For more than 90 years, the cable car <i>Nebelhornbahn</i> took numerous guests up into the heights. Now it can go into well-earned retirement. Starting in the summer of 2021, a new cable car will transport enthusiastic outdoor fans to the mountains on the Nebelhorn. The aim of the project is to avoid long waiting times, provide seated transportation with an optimal view at every seat and increase the carrying capacity.</p>																			
<p>Technical data of the old cable car:</p> <table> <tr> <td>Model:</td> <td>Large-cabin aerial tramway</td> </tr> <tr> <td>Weight empty cabine:</td> <td>1600 kg</td> </tr> <tr> <td>Weight full cabine:</td> <td>3900 kg</td> </tr> <tr> <td>Height valley station:</td> <td>1933 m</td> </tr> <tr> <td>Height top station:</td> <td>2214.2 m</td> </tr> <tr> <td>Horizontal difference:</td> <td>905.77 m</td> </tr> <tr> <td>Speed:</td> <td>8 m/s</td> </tr> <tr> <td>Carrying capacity:</td> <td>500 persons/h</td> </tr> <tr> <td>Power unit:</td> <td>120 PS</td> </tr> </table>			Model:	Large-cabin aerial tramway	Weight empty cabine:	1600 kg	Weight full cabine:	3900 kg	Height valley station:	1933 m	Height top station:	2214.2 m	Horizontal difference:	905.77 m	Speed:	8 m/s	Carrying capacity:	500 persons/h	Power unit:
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Figure 1: Real-world situation used as a stimulus for modelling-related problem posing

Problem posing and interest in solving self-generated problems

Motivation is an important variable that affects students' behavior, decisions, and performance (Middleton & Spanias, 1999). Closely related to students' intrinsic motivation is students' interest, which is defined as a person-object relationship that refers to both the state of attention and affect toward a particular topic (situational interest) and an enduring predisposition to reengage with a topic over time (individual interest) (Hidi & Renninger, 2006). Learning environments can foster the development of individual interest by triggering situational interest and building upon prior individual interest (Hidi & Renninger, 2006). Problem posing provides opportunities to generate problems according to a person's own interests, and thus, incorporating problem posing in class has the potential to improve students' motivation (Cai & Leikin, 2020). Prior research has shown that teaching interventions that include problem-posing activities positively affect students' individual interest in mathematics (Xia et al., 2008) and their situational interest in the topic that is being addressed in class (e.g., algebra) (Walkington, 2017). However, the extent to which students' interest influences their decision to generate a certain problem is an open question. Learners' affect and more specifically learners' interest could refer to different objects (Schukajlow et al., 2017). For modelling-related problem posing, they could either center their interests on the real-world context or on an inherent intramathematical topic. In addition, the people whose interests are being evaluated might differ. If teachers pose problems for their students, they might refer more to what they think their students find interesting than to their own interest. Preservice teachers might already identify with their role as teachers, but it is also possible that they still identify more with the student role, particularly because they do not yet have students of their own to relate to.

Problem posing and self-efficacy in solving self-generated problems

Self-efficacy is defined as the perceived ability to successfully perform an action in the future (Bandura, 1997). Prior research has demonstrated that self-efficacy is positively related to performance and is an important factor that influences students' decisions while learning (Pajares, 1996). For problem posing, the criteria for estimating students' success varies according to the goals of constructing a problem. Voica et al. (2020) showed that self-efficacy in problem posing occurs in relation to several goals. The preservice teachers investigated in this study reported on their self-efficacy to construct a large number of problems, difficult problems, original problems, or problems that matched the abilities of a problem-solver. Further, a person's problem solving self-efficacy could also influence his or her decision to pose a certain problem because learners might generate only the kinds of problems that they are confident they can solve. This could explain why learners tend to pose simple and closed-ended problems (English, 1998; Hartmann et al., 2021). The present study is aimed at shedding some light on this potential reason. As the participants of our study were preservice teachers, it is also possible that their expectations refer more to the success of their students than to their own expectations of success with respect to being able to solve the problem. However, it is also possible that preservice teachers consider it as particularly important that they are themselves able to solve their self-generated problems, because they might imagine their future selves as teachers. The study of Marschall (2021) shows that preservice teachers' self-efficacy appraisal is closely related to narrative self-schema and the development of professional identity. Thus, it is important to take into account the different perspectives they adopt when evaluating their problem posing process or the potential success of a student in solving the problem.

Research questions

The aim of the present study was to investigate the role of interest (RQ1) and self-efficacy expectations (RQ2) in problem posing. In particular, our research questions were:

RQ 1a: What are the objects of interest that preservice teachers refer to when posing problems?

RQ 1b: What are the perspectives of preservice teachers when they evaluate interest?

RQ 2: What are the goals that preservice teachers' self-efficacy refers to?

Method

Sample and data collection

Seven preservice teachers (three women, four men; between the ages of 20 and 26 years) from a German university participated in the study. The preservice teachers participated voluntarily in the study and were selected under maximum variation sampling criteria in order to gather information rich data and to analyze the existence of patterns across the variation. As selection criteria, we focused on their mathematical performance levels, their experience with problem posing and solving, and on their study programs. Five of the preservice teachers studied for a teacher profession at high track secondary schools and two of them for a teacher profession at middle track secondary schools. Four of them were in a master program and three in a bachelor program. Pseudonyms were used for the names of participants. In a laboratory setting, each of the participants received three real-world

situations (Cable Car, Fire Brigade, Chopsticks) with the request to first pose problems on the basis of the given situation by instructing them “Read the description of the situation aloud. Then you think about what mathematical question you can ask yourself about the situation.” and afterwards to solve their problems. One of the situations is depicted in Figure 1. A shortened version of the other problems is presented in Table 1. After posing and solving the problems, the participants were asked in stimulated recall interviews about why they generated the particular problems at hand. The interviews were video-recorded, the video material was transcribed and sequenced into classification units.

Table 1. Shortened version of the additional problem posing stimuli

Fire Brigade. The Muenster fire department has a total of 16 locations in downtown Muenster, so that there is a maximum distance of 6 km from a burning house. On average, a truck manages to drive about 40 km/h in Muenster city traffic. A central component of the Muenster fire-brigade is a fire engine with a turn-ladder. The dimensions of such a fire engine with a 30 m turn ladder are specified in the fire department’s guidelines. [Table with data about the fire engine]. Using a fire-engine the fire-brigade can rescue people from great heights. The rescue is carried out via a cage attached to the end of the ladder. [...] So called HAUS-rules, in which minimum distances of the vehicle are specified are applied [List with distance rules]. [Picture of a fire engine]

Chopsticks. Lisa is looking online for a gift for her mother’s birthday. [...] Lisa decided to buy her mother chopsticks. She finds the following offer: [Picture with product details including the price, and the length of the chopsticks, and the number of product reviews]. Lisa finds a nice storage box for the chopsticks [Picture with product details including measures, weight, price and product rating]. To save some money, Lisa researches online for a discount promotion. She discovers a discount promotion where she gets a 10% discount on her entire purchase if her purchase is worth 20€ or more, and a 20% discount if her purchase is worth 30€ or more.

Data analysis

A qualitative approach was used for this study to gain in-depth insights about preservice teachers’ reasons for posing a certain problem. We focused on preservice teachers’ interest and self-efficacy, because these constructs revealed as important during the interviews. The transcripts were analyzed using a qualitative content analysis. A category system was developed using a data-driven approach. The sequences were coded with regard to the objects of interest, the perspective of interest, the goals of self-efficacy expectations and the perspective of solving expectations. The material was analyzed by a trained coder; the coding was discussed among the members of the research team using consensual coding principles and checking for reliability (Cohens’ $\kappa \geq .662$).

Findings

An overview of central categories and sub-categories that were derived from the material is presented in Table 2.

Table 2. Categories for reasons that explained the self-generated problems

Main category	Subcategory	Description	Example
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Objects of interest	Interest in the answer	Interest in the answer to the posed problem	...because I was interested in knowing whether the chopsticks were free.
	Interest in the real-world situation	Interest in specific aspects of the real-world situation	...because if I think about what I find most interesting...
	Interest in the mathematical topic	Interest in the mathematical topic that is related to the problem	...because I like to have tasks with functions.
Perspective of interest	One's own interest	Statement of interest refers to the preservice teacher's own interest	...what I am personally interested in.
	Interesting to the protagonist	Statement of interest refers to the protagonist's interest	...I thought about what Lisa wanted to know.
	Interesting for students	Statement of interest refers to the interest of the imaginary students who would work on the problem	...because I thought that would be interesting for the students to know.
Goals of self-efficacy expectations	Solving	Reasons that address the problem-solver's self-efficacy with respect to solving the problem	...that I am able to solve the problem.
	Posing	Reasons that address the problem-solver's self-efficacy with respect to mastering problem posing	...that I am able to construct a problem with an adequate level of difficulty

Preservice teachers' interest in posing problems

Interest was often mentioned by the preservice teachers when explaining why they decided to pose a certain problem. Thereby the participants referred to different objects of interest. Most frequently they were interested in the answer of their self-generated problem (18 sequences, 5 out of 7 participants). For example, Anna posed the following problem to the Chopstick task: "How much money can Lisa save?" She explained that she posed this problem because she wanted to know whether or not the chopsticks would be free.

Anna: (Chopstick task) Hm, [...] Definitely interesting for me too, because [...] I was also interested in whether the chopsticks would ultimately be free, that is, were given for free.

Their interest in aspects of the real-world situation was also often mentioned by explaining their decision to pose a certain problem (9 sequences, 5 participants). For example, Theo said that he included his personal interests in his problem posing process.

Theo: (Cable car task) [...] and then I have linked the [...] knowledge [...] with what would be of further interest to me personally. [...] So [...] How does it look if I [...] in particular limit the people to the window seats [...].

In addition, interest in the mathematical topic behind the problem was mentioned by three participants (3 sequences).

Further, differences were found regarding the perspective of who might find the problem interesting (Perspective of interest). Most preservice teachers referred to their own interest or what in general could be seen as interesting (15 sequences, 6 participants). However, some participants took the perspective of the protagonist of the given real-world context and generated a problem that they thought would be interesting for this person to solve (7 sequences, 4 participants).

Theo: (Chopstick task) So practically I put myself in her [the protagonist's] position [...] and thought I would like to save money on the one hand, but also have as many chopsticks as possible [...].

One participant (Lea) also took the perspective of an imaginary student who could work on the problem (2 sequences).

Lea: (Fire brigade task) Because I also thought that the students might be interested in this. Or because they understand why they / because they don't think: This is a useless task [...] well, because somehow you [...] understand why you want to know.

Preservice teachers' self-efficacy when posing problems

Regarding self-efficacy, we found that the preservice teachers in our sample often referred to their self-efficacy expectations to explain why they posed a certain problem. In particular, their expectations that they would be able to solve the self-generated problems played a major role in posing the problem. (12 sequences, 5 participants).

Fabian: (Chopstick task) It was not a known task, but of course a task that I could solve myself, that / exactly. Um, now with this task, I already had my solution method in my head. So, I knew straight away how / how to / so I didn't have to think about the right solution for a long time but already knew the procedure, um how to proceed.

In addition, their self-efficacy expectations of mastering problem posing was also mentioned by two of the participants (4 sequences). Thereby, the preservice teachers set different goals that they wanted to achieve. One of the participants (Leon) wanted to pose multiple problems with increasing difficulties. For each situation, he constructed at least three problems, beginning with an easy problem and ending with a difficult one.

Leon: (*Cable car task*) Again from easy to difficult. In the beginning, it was [...] the simple task with the Pythagorean theorem [...] um, and then it should get more and more difficult with a variable [...] that has to be calculated.

For the cable car situation, Leon generated the following four problems (Figure 1): "How long is the distance between the valley and the mountain station? How much time does it take to go one way? What is the maximum number of times per hour that the cable car can run? How many people would be in the cabin on average?"

Lea had a different goal, for her it was important to construct problems with an appropriate level of difficulty.

Lea: (*Cable car task*) So it was a compromise between: It's not too difficult, it's not too easy, it's somehow feasible.

The preservice teachers' expectations for solving the problem mainly referred to their own self-efficacy (11 sequences, 5 participants). However, the one participant (Lea) who considered students' interest also took into account students' potential solving success and constructed a problem that she was confident the students would be able to solve.

Summary and discussion

In the present study, we investigated how interest and self-efficacy contribute to preservice teachers' decisions to pose a certain problem. Our findings support the idea that problem posing could be a powerful tool to foster motivation (Cai & Leikin, 2020). The preservice teachers in our study often posed problems to which they were interested in knowing the answer. This indicates that learners use the opportunity that problem posing provides to integrate their interests in their problem-posing processes. Their interest in the answer of the self-generated problem might have benefits for their perseverance and the effort they put into problem solving or might positively affect their interest in the math that is needed to solve the problem (Walkington, 2017) or might contribute to their interest in mathematics in general (Xia et al., 2008). Future studies should investigate how this potential of problem posing can be used in learning environments that are aimed at fostering students' motivation. Our findings highlight the importance to distinguish between objects of interest (Schukajlow et al., 2017). Besides interest in the answer and in certain aspects of the real world situation, interest in the mathematical aspects behind the problems was also a reason for preservice teachers' self-generated problems. Further, preservice teachers mostly referred to their own interest, but they also took other perspectives and generated problems that they thought would be interesting to the protagonist of the real-world situation or to the students who would be working on the problems.

In addition, we focused on the role that preservice teachers' self-efficacy expectations play in problem posing. We found that some of the learners stated that it was an important criterion for the self-generated problems that they were confident they could solve the problems themselves. This contributes to explaining learners' tendency to pose simple problems as found in prior studies (English, 1998; Hartmann et al., 2021). However, in line with the results from the study conducted by Voica et al. (2020), their self-efficacy referred not only to their expectation that they would be able to solve the problem but also to their expectation that they could successfully pose a problem. Thereby, constructing multiple problems and constructing problems with an appropriate level of difficulty were identified as problem-posing goals. This finding exemplifies the idea that preservice teachers' self-efficacy appraisal is linked to their different roles such as their role as future teachers (Marschall, 2021). In addition, it shows the importance to take into account different goals associated with problem posing. For further research it seems necessary to better understand these goals to develop evaluation criteria to assess problem posing performance.

As a practical implication, our study shows that it was important for the preservice teachers to construct problems that they were confident they would be able to solve. When teaching problem posing in class, it therefore seems necessary to encourage students to also pose difficult problems that allow for progress in their learning. In addition, teachers should be aware of the different goals that come up with problem posing (e.g., posing multiple problems) and make them transparent to the students.

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