Preservice teachers' mathematics-related values and expectancy of success in their first study year

Valores relacionados com a matemática e expectativas de sucesso dos futuros professores no seu primeiro ano de estudo

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Abstract. Many preservice mathematics teachers lose their motivation during their first year at university. This phenomenon has been repeatedly described in recent years but is not yet fully understood. Since motivation may relate to different objects such as mathematics or teaching, we aim to qualitatively reconstruct different facets of the central motivational constructs of Situated-Expectancy-Value theory (intrinsic value, attainment value, utility value, cost, and expectancy of success) for preservice mathematics teachers. The analysis of longitudinal group interviews of 14 preservice higher-secondary mathematic teachers from a German university revealed different objects of motivation (e.g., teaching mathematics, scientific mathematics, procedural mathematics, or proof-based mathematics) in preservice teachers' values and expectancy of success. Furthermore, relations between those values and expectancy of success were identified that played a significant role in preservice teachers' motivational development over their first semester (e.g., relations of attainment value for scientific mathematics and psychological cost). Theoretical and practical implications towards a teaching-specific conceptualization of expectancy of success and values and value interventions are being discussed.

Quadrante: Revista de Investigação em Educação Matemática 32(2) 25-48
https://doi.org/10.48489/quadrante.31191
Received: May 2023 / Accepted: December 2023

Keywords: Situated Expectancy-Value theory; identity; teacher education; longitudinal qualitative study.

Resumo. Muitos futuros professores de matemática perdem a sua motivação durante o primeiro ano na universidade. Este fenómeno tem sido repetidamente descrito nos últimos anos, mas ainda não é totalmente compreendido. Uma vez que a motivação pode estar relacionada com diferentes objetos, como a matemática ou o ensino, o nosso objetivo é reconstruir qualitativamente diferentes facetas dos construtos motivacionais centrais da Teoria de Expectativa-Valor Situados (valor intrínseco, valor de realização, valor de utilidade, custo e expetativa de sucesso) para os futuros professores de matemática. A análise de entrevistas de grupo longitudinais a 14 futuros professores de matemática do ensino secundário de uma universidade alemã revelou diferentes objetos de motivação (por exemplo, o ensino da matemática, a matemática científica, a matemática processual ou a matemática baseada em provas) nos valores e expectativas de sucesso dos futuros professores. Além disso, foram identificadas relações entre esses valores e expectativas de sucesso que desempenharam um papel significativo no desenvolvimento motivacional dos futuros professores durante o primeiro semestre (por exemplo, relações entre o valor de realização da matemática científica e o custo psicológico). São discutidas as implicações teóricas e práticas para uma concetualização específica do ensino da expetativa de sucesso, dos valores e das intervenções sobre os valores.
Palavras-chave: Teoria de Expectativa-Valor Situados; identidade; formação de professores; estudo qualitativo longitudinal.

Introduction

Motivation, here in terms of values and expectancy of success (Eccles & Wigfield, 2020), is a central variable in teacher education. It is an essential predictor for study retention (Schnettler et al., 2020), study satisfaction (Wach et al., 2016), and future learning success (Biermann et al., 2019). Motivation also relates to the use of learning opportunities and the quality of teaching in internships (Biermann et al., 2019), as well as to burnout risks for first-year teachers (Reichl et al., 2014).

However, when it comes to preservice mathematics teachers (PST), specifically to PST for higher-secondary education (grades 5 to 13), they often describe a loss of motivation during their first year of studying (Liebendörfer, 2018; Rach, 2014). They report being unsatisfied with their studies and heavily question the relevance of mathematical courses for their future profession (Tattoo et al., 2012; Wenzl et al., 2018).

Cognitive challenges in the first study year in mathematics may partly explain this phenomenon (Gueudet et al., 2016). Qualitative studies, however, highlighted that also high achieving PST struggled with motivation for mathematics (Göller, 2022). Thus, further reasons may be underlying PST's loss of motivation. Gildehaus and Liebendörfer (2021), for example, found that PST may experience tensions between teaching and mathematics communities. Recent approaches also considered different facets of PST's motivation, stating that mathematics could be one of many reasons to become a PST. One may also be motivated for teaching in general, e.g., a job where one interacts with young people or that is quite secure and well-payed (Fray & Gore, 2018; Neugebauer, 2013).

To understand PST's motivational development, we investigate their motivation from their perspective and their motivational development during their first year of study. The research should identify possible facets of student motivation and their interaction. This could help to foster their motivation and prevent motivational decrease from a long-term perspective. Given this possible multifaceted motivation of PST in teaching and mathematics, we use Situated-Expectancy-Value Theory (SEVT; Eccles & Wigfield, 2020) to frame their motivation. The framework allows us to focus on different values that refer to different facets of their motivation but still fit into one coherent model.

Theoretical background

Situated-Expectancy-Value Theory

SEVT posits that an individual's motivation is directly related to two sets of beliefs: the importance or value the individual attaches to a specific action or task (Do I want to do this?) and the individual's expectancy for success (Can I do this?; Eccles, 2007). The values are multifaceted: individuals may value a task because it is interesting or enjoyable (intrinsic value; e.g., they enjoy studying mathematics), because it is useful for their current or future goals (utility value; e.g., they see studying mathematics as useful for their future career) or because it is important to their identity (attainment value; e.g., they see themselves as mathematicians and therefore value studying mathematics; Eccles, 2007; 2009). Identity can broadly be understood as "being recognized as a certain 'kind of person,' in a given context" (Gee, 2000, p. 99). Thus, PST identifying themselves with mathematics value what they and others would recognize as mathematicians or as mathematical. A further component of values is perceived costs, defined as the perceived drawbacks of engaging in a task. Most common are opportunity costs, effort costs and psychological costs. If a task prevents one from being able to participate in other valued tasks, it has high opportunity costs (e.g., not having enough free time while studying mathematics). If a task requires particularly high effort, it has high effort costs (e.g., studying mathematics requires a lot of effort and time; Eccles & Wigfield, 2020). Psychological costs arise if performing a task is related to high levels of negative emotions (e.g., being anxious while studying mathematics).

While Eccles (2007) often relates values and expectancy towards a specific task or similarly, action, we understand that motivation is more generally related to different objects, that can be on different hierarchy levels (Schukajlow et al., 2023). Thus, one can be motivated for mathematics in general, as well as for a specific mathematical task.

Motivation for becoming a teacher and studying mathematics at university

In the following, we report how PST's motivation as seen from a SEVT perspective is linked with different objects in current research. Several studies mirror that PST's values and expectancy may be related to different objects. In particular, teaching and mathematics are discerned (Kunter et al., 2008). However, some authors refer to slightly different objects.

For *intrinsic value*, Pohlmann & Möller (2010) suggested conceptualizing two objects, a subject-specific interest, and a pedagogical interest. Somewhat similar, Kunter et al. (2008) discussed that the interest of PST could be considered two-dimensional discerning mathematics from mathematics teaching. Since mathematics in school is often based on procedures and calculation, whereas mathematics at university is based on logic, formalism, and proof, Ufer et al. (2017) investigated different objects of mathematical interest at both the institutional and activity levels. PST reported higher interest in school mathematics than in university mathematics and higher interest in procedures than in proofs and formalism (Ufer et al., 2017). Furthermore, their interest in university mathematics decreased during their first semester, which was predictive for their study satisfaction (Kosiol et al., 2019).

For PST's *attainment value*, no such differentiations exist to our knowledge. However, identity research, which seems relevant given an identity-based conceptualization of attainment value, did provide insights in the last years: Scholars found that PST often had to negotiate between different communities and practices and experienced several identity tensions, e. g. between reform and standard-oriented teaching (Gainsburg, 2012), theory and practice (Solomon et al., 2017), as well as teaching and mathematics (Gildehaus & Liebendörfer, 2021; Gildehaus et al., under review). Different objects in PST's attainment value thus seem likely. Furthermore, for STEM fields in general, attainment value is most predictive of study retention (Robinson et al., 2018; 2019). It usually decreases during the first year, negatively predicting study retention (Schnettler et al., 2020).

Regarding PST's *utility value*, there are several discussions. Being a teacher means having a secure and well-payed job (in the German system). Thus, PST usually report utility value for the object of the job (Göller & Besser, 2021; Watt et al., 2012). However, when it comes to the object of the subject-specific content, many PST perceive an incongruity between university mathematics courses and (secondary) mathematics teaching (Goulding et al., 2003; Zazkis & Leikin, 2010) and thus rate mathematical contents at university as irrelevant for their future career as teachers (Tatto et al., 2012; Wenzl et al., 2018). Accordingly, the utility value of the contents usually strongly decreases during the first semester, which often relates to a decrease in study satisfaction (Eichler & Isaev, 2017). Furthermore, recent research addressed the perceived relevance students attributed to different objects of mathematics, which seems closely related to utility value (Hernandez-Martinez & Vos, 2018).

Cost is known to be pretty dominant in first-year mathematics students motivation (Ko & Marx, 2019). Cost increases are common (Perez et al., 2019) and negatively predict study retention (Schnettler et al., 2020). Most costs in mathematics are related to cognitive struggle (Feldon et al., 2019). However, there are no specific insights into PST's cost to our knowledge.

Similar to intrinsic value, Pohlmann & Möller (2010) conceptualized two objects for PST's *expectancy*: one for teaching in general and one for the subject to be studied. Rach et al. (2021) distinguished two objects in PST's self-concept on an institutional level regarding school mathematics and university mathematics. Self-concept for university mathematics positively predicts study satisfaction, but PST's self-concept for university mathematics decreases during the first semester (Rach et al., 2021).

Values and expectancy are usually related to each other (Perez et al., 2019). However, it is unclear if specific relations occur, for example, between PST's different motivational objects. Liebendörfer and Schukajlow (2020) found that the quality of PST's reflection on utility value was related to their mathematical interest, which is closely related to intrinsic value. In contrast, Rach (2022) found that an intervention with exercises providing connections to school-based mathematics was increasing PST's utility value but no other dimensions of their motivation. Perez et al. (2014) investigated how identity was related to attainment value. Facing the possible identity tensions as a PST between different communities, different objects of attainment value may be conflicting as well and thus be positively related to cost.

In summary, the current state of the art strengthens the perspective that looking at different objects for PST motivation can contribute to understanding their motivation in general. However, the specific differentiations are limited to intrinsic value and expectancy.

Given the many factors that may underlie PST's motivation according to the cited qualitative research, we aim to add to this theoretical perspective a student-centered perspective. To differentiate objects of motivation, we will refer to teaching and mathematics. Teaching refers primarily to PST roles as teacher in school but includes related activities such as explaining. Mathematics includes both school content and study content. Teaching and mathematics may overlap, but also each provide their own parts. We follow a deductive-inductive approach, identifying relevant objects and structures in PST's values and expectancy. Since the decrease in motivation is particularly high in the first semester, we focus on this period.

Research Questions

RQ1: What mathematics-related and teaching-related values and expectancy do PST describe in their first semester of studying mathematics?

RQ2: How do these values and expectancy change during the first semester?

Methods

Sample

The study was located at a medium-sized German university where, in their first semester, PST attended one course (linear algebra, LA) together with mathematics majors and one bridging course specific for PST (introduction to mathematical thinking and working, IC). The LA course had lectures twice a week and tutorials once a week. Students had to earn points (at least 33%) on weekly homework to be admitted to the final exam. In the IC course, lectures and tutorials were each given once a week. Students had to pass two short exams during the semester as well as reach 50% on their weekly homework to participate in the final exam. The second semester was held mainly online due to Covid-19. Students attended online tutorials once a week in the LA course and watched asynchronous lecture videos.

Participating PST answered an open call for the first interview. We interviewed three groups with four to five PST each (n=14; 8 female, average age: 19.5, range: 18-23). Groups had been formed by the PST themselves. Unfortunately, due to the pandemic in the next term, we struggled to reach the PST again for the scheduled second interview. In total, we could reach five (n=5) PST again for the second interview, of which four were still working together in a group. One PST was interviewed alone.

Data collection

We collected our data using longitudinal semi-structured group interviews. The group interviews were used in order to contrast different perceptions of expectancy and values among the PST (Gibbs, 2012).

The interviewer deliberately did not explicitly address mathematics-related values to maintain an open character. First, we asked the PST about their recent experiences and feeling in the current situation, followed by a retrospective of why they chose to become mathematics teachers. Second, the open entrance was followed by more specific questions on their expectancy and values related to their studies, e. g., what they liked or disliked in their studies and how they could identify themselves with their studies.

The first interviews took place in person two months after the first semester had started. Participants were guaranteed anonymity and had no further contact with the interviewer.

The second interviews were held at the end of the second semester and were taken via Zoom due to the pandemic. The interview guide was the same, except that PST were also asked to compare their experiences to the previous interview.

Data analysis

For both research questions we used the data from both interviews since this provided us a richer picture. For RQ 1, data were analyzed using a structuring content analysis based on deductive coding, which was followed by a concluding content analysis based on inductive coding (Mayring, 2014). We referred to a conceptualization of values as a continuum, where a range between high to zero is possible (Eccles & Wigfield, 2020). Accordingly, some segments were coded with more than one category. Our deductive categories followed the theoretical framework of SEVT, examples and descriptions are given in Table 1.

Table 1. Coding categories with brief descriptions and examples

Category	**Referring to (lack of)**	**Example quote**
Intrinsic Value	enjoyment, fun, etc.	When you've managed to write down a proof correctly, there's a brief moment of joy.
Attainment Value	relevance to one's identity	So, math is not my big love, not that I'm happy like a mathematician in my math world, but I would like to teach it to someone.
Utility Value	usefulness	I have to be able to do this [referring to the content of the LA II lecture] now until the exam. After the exam, I can safely forget it again.
Cost	any kind of drawbacks	Then the question for me is, do I continue my studies at all? (...) That puts me under complete pressure. I don't know how many times at the weekend I sat at home crying.
Expectancy	what PST felt able to perform or handle (current or in the future)	We might have managed the exam with a lot of luck, but that wouldn't have gotten us any further.

In the next step, we inductively summarized the individual coding segments in each category, e.g., when PST discussed liking a specific kind of mathematics several times, those segments were summarized into new subcodes of intrinsic value. This resulted in a second category system presented in the findings (Table 2). All categories were identified at least once in both interviews.

For RQ 2, individual cases were reconstructed for all PST of the longitudinal sample. These included basic information on their gender and subjects as well as their described values in the first and second interviews. Following Matusovich et al. (2010), we referred to a naive categorization of "high and low" values (based on interpersonal comparisons of the interviewed PST) and "decreased" or "increased" values (based on intrapersonal comparisons), to roughly describe PST's motivational developments. For example, "I can find my way around it [mathematics at university] better now. So, I know how to get to solutions." was seen as increase of expectancy.

We selected three PST for presentation in the findings following a theoretical sampling (Suri, 2011): Greta and Marie were chosen as "norm cases" that described two different developments, that were also seen with two more PST (Hering & Jungmann, 2022, p. 621-

623). Louisa was chosen as an "extreme case", reporting an increase in motivation instead of a decrease. We contrasted the three cases chosen for presentation regarding their different objects of motivation and motivational development.

Findings

We present the findings for each research question sorted by the different categories that occurred. Quotes are given with pseudonyms that are coherent with the reported gender of the PST. The number attached to the names indicates the first or second interview.

Research Question 1

Intrinsic Value

All PST pointed out differences between their Intrinsic Value for the mathematics they knew from school and the mathematics they got to know at university (Greta_1: “this, what we are doing *here*.”). Furthermore, while PST all referred to liking or enjoying mathematics at school, they underlined that they were not enjoying it anymore at university (Bea_1: “*here* it is just no fun”).

The experienced intensity of Intrinsic Value of university mathematics seemed to be negatively related to the level of formal and proof-based content that was introduced in the university courses. For example, the pre-course that contained basic proofs in number theory and introduced different types of mathematical proofs on a basic level was seen as “interesting” (Kira_1), and the teaching-specific bridging course in the first semester as “really okay” (Marie_1) or even “gives a good feeling” (Louisa_1). In contrast, the LA course in the first semester was described as “no fun” (Ronja_1) or even “simply nuts” (Kevin_1).

PST’s Intrinsic Value of mathematics in school was based on enjoying applications and procedures:

> Marie_1: I liked so much [that, in school] there was a procedure (…). So, I learned that once and then you could just apply it like that.

Similarly, procedures in university mathematics were also described as enjoyable. However, procedures were contrasted against proof-based mathematics:

> Marie_2: And because it's really just a matter of calculating. It's a procedure, you know exactly what you have to do. (...) Which is simply not the case with the proofs because it's often like this, okay, you go one step forward, and then you go two steps back again. (…) That's why it's more these calculating problems [procedure-based] that give me pleasure.

Hence, while school mathematics and university mathematics were the broader objects of Intrinsic Value on an institutional level being brought up by the PST, procedure and proof-based mathematics seemed to be the related differentiation of objects at the level of mathematical activities.

Another object where Intrinsic Value related to mathematics was described was teaching mathematics. Here, PST described how they enjoyed tutoring children (Bea_1) or explaining mathematics to their peers (Louisa_1). More concretely, this enjoyment of teaching mathematics was specifically related to explaining mathematics to students and providing "moments of understanding" for them:

> Louisa_2: It's great now in class because you have this "ahh" experience. (...) when students [in school] are really happy, ah yes, I've understood. It's really great in math (...) when you realize that your explanation really helps somehow, and then you see how they find things easier and easier. That's cool.

Concluding, we found that Intrinsic Value was related to three different objects in university studies: the joy of doing procedural mathematics as it often happens at school but at university as well, the joy (or here: absence of joy) of doing proof-based mathematics, and the joy of teaching mathematics.

Attainment Value

Following our conceptualization of Attainment Value as related to one's identity, we found two objects based on different identities the PST described.

One object was related to PST's identity of becoming mathematics teachers. Teaching was seen as the "dream job" (Louisa_1). Linked with this identity was the recognized practice of explaining mathematics to someone, which was highly valued. All PST agreed that as a mathematics teacher, one has to be good in explaining, and most PST described that explaining was relevant and valuable to them when they saw themselves as future teachers.

> Greta_1: Well, they [referring to mathematics major students] want to do something with math. I mean, me too, but I want to teach and explain it to students.

In line with this was the idea of being an extroverted, social person that "stands in front of a class one day" (Marc_1). Thus, helping each other out with homework (Marie_2: "you always know you can rely on each other") and explaining things to each other in group work were valued practices that were in line with the mathematics teacher identity:

> Marie_2: Preservice teachers are perhaps much more open in comparison [to mathematics majors], they [preservice teachers] like to talk a lot and also have no problem teaching or explaining things to other people.

We thus named this category Attainment Value for Teaching. The second object of the Attainment Value was based on a scientific mathematical identity. PST here described their perception of mathematics and mathematicians at university, where proofs and deeply understanding mathematics were related to one's identity (Greta_1: "I am a person that has to understand, I really want to understand"). In line with this was the feeling of exclusivity as mathematicians, communicating in a way that people with a non-mathematical background could not understand:

Ronja_2: So when I have my LA lecture notes there and when someone from my friends is there, sometimes I have to show them [the lecture notes] and say, "Yeah. Yeah. I actually understand that." So those are the little moments when I'm a little bit proud.

We named this category Attainment Value for scientific mathematics. Our identity-based conceptualization of Attainment Value thus showed two objects. One object was based on identities as mathematics teachers, where explaining and being social were valued. Another object was based on identities as scientific mathematicians, where proving, deep understanding, and exclusivity were valued.

Utility Value

Most dominant in PST's discussion about Utility Value was the object of mathematical content at university, specifically proof-based mathematics and formal content. However, we found two different utilities that were related to the same object. We named these content-based Utility Value and degree-based Utility Value. Content-based Utility Value was related to the PST's assumptions about what they would need and use in their future job as teachers, while degree-based Utility Value described the perceived relevance of content for passing the exams and reaching the formal requirements of becoming a teacher. Max and Sarah described the content-based dimension:

Max_1: I think it also depends on the concrete theme. So, there are things you need to know as a [mathematics] teacher. But I mean, for example, indexed quantities or so. (…) you don't teach that [in school], so you don't need it.
Sarah_1: It is simply not in the [school] curriculum.

This absence of content-based Utility Value was seen as being specific to mathematics. All PST described perceiving more relevance and Utility Value attributed to the contents they learned in their second subjects.

In contrast, most of the PST described their Utility Value of studying mathematics in terms of the formal degree (degree-based Utility Value):

Bea_2: And then a lot of people say, "Why do you do it at all if you don't enjoy it?" And I'm like, yeah, there's no other way, right? It's just

> the way to get there. And you still have this goal [of becoming a mathematics teacher] somehow.

Facing this formal usefulness, the only relevance of the contents of the university courses was to gain enough points in exercises to participate in the exam and pass the exam.

Concluding, Utility Value was focused on the object of mathematical content but structured into two directions in our interviews.

Cost

We could not clearly identify various teaching- or mathematics-related objects for Cost. Instead, the three broader dimensions of Opportunity, Effort and Psychological Cost given by Eccles (2005) appeared to be the most dominant.

All PST described that mathematics would prevent them from focusing on their second subject, and thus, studying mathematics had high Opportunity Costs. While technically, both subjects of the teaching program had the same amount of credits and time to invest and thus were positioned equally, PST argued that their second subjects would receive less time and effort: “Sport feels like my second subject. Not like a second major, but like a minor” (Sarah_1).

Effort Cost was mainly discussed in relation to the weekly exercises (Marie_1: “It is just impossible in terms of time because this homework just takes up so much time”), but also more generally. All PST agreed that a lot of time and effort was required to study mathematics:

> Sarah_1: You really devote yourself to math. You have math lectures and math tutorials almost every day. Then the exercise sheets, which you have to finish within the week. And then you're just glad that you've handed them in, and then the next one is already there. (…)

Specifically, proofs were seen as requiring a lot of effort, as described by Marie:

> Marie_2: With the proofs, (…) it's often like, okay, you take one step forward, and then you take two steps back again.

Psychological Cost was mainly associated with frustration when working on the exercises. For example, PST described feeling stupid, angry, or sad when they could not get a solution, which sometimes made them think about “just quitting my whole studies” (Greta_1) or not handing in the homework like Marc described:

> Marc_1: Well, sometimes there are moments when you really sit in front of it [the homework], and you don't understand a single word of the stupid task, except for 'prove' or 'show' (…). And you really think to yourself, ‘no way’. Like, you really started it [the homework] with hope (…), and then [it is like] you get a verbal slap in the face. (…) Where I think to myself, wow, no way I will be handing in this homework.

In general, Cost appeared to be very dominant in PST's descriptions. All cost dimensions were related to mathematics as the object and Effort Cost was specifically related to the object of proof-based mathematics. The identified Opportunity Cost towards the second subject seemed specific for PST.

Expectancy

Similar to the differentiations of Intrinsic Value, PST also differed between two types of mathematics when relating to their Expectancy. While they all described high expectations of success at school mathematics (Louisa_1: "I mean, good grades in math, you just had them."), they highly struggled with mathematics at university (Marc_1: "you don't understand a single word of the stupid task, except for 'prove' or 'show'.")

Similar to Intrinsic Value, PST's Expectancy did not only differ on an institutional level between mathematics in school and at university but also between mathematical activities of procedural or proof-based mathematics:

> Greta_2: Math in school is just calculating, and I can do that. I can also do the stuff in the exercises [referring to the homework at university] where you have to do the calculations. That's easy for me.

Their Expectancy in proof-based mathematics was contrasted against procedure-related Expectancy (Greta_1: "When it is about calculating, then it is okay. But all those proofs!").

Similar to Intrinsic Value, we found the object of teaching mathematics that was mentioned by most of the PST:

> Marie_1: I think we would all already be in a position to teach children something. Because it's obvious that we've all done some tutoring or something similar.

Thus, all identified objects of PST's mathematics-related Expectancy correspond to those of Intrinsic Value.

Overview of Research Question 1

In Table 2, we provide an overview to the identified subcategories of each Value.

Table 2. Overview of identified objects in PST's values and expectancy

Value	Object or structure	Example
Intrinsic Value	Procedural mathematics	I liked so much [that, in mathematics in school] there was a procedure.
	Proof-based mathematics	It's a procedure, you know exactly what you have to do. (...) Which is simply not the case with the proofs (...) that's why it's more these calculating problems [procedure-based] that give me pleasure.
	Teaching mathematics	That math could be fun for me as a teacher.
Attainment Value	Scientific mathematics	I have my LA lecture notes there, and (...) my friends [are] there, sometimes I have to show them [the notes] and say, "Yeah. Yeah. I actually understand that." So those are the little moments when I'm a little bit proud.
	Teaching mathematics	Well, they [referring to major students] want to do something with math. I mean, me too, but I want to teach and explain it to students.
Utility Value	Future teaching lessons	Whether that [referring to the LA course] is really necessary for us to be good math teachers is the question.
	Formal degree of the study program	"Why do you do it at all if you don't enjoy it?" And I'm like, yeah, there's no other way, right? It's just the way to get there [become a math teacher].
Opportunity Cost	Mathematics and the second subject	Sport feels like my second subject, not like a second major, but like a minor.
Effort Cost	Mathematics, specifically proofs	With the proofs, (...) it's often like, okay, you take one step forward, and then you take two steps back again.
Psychological Cost	Mathematics	I am afraid of the upcoming exams.
Expectancy	Procedural mathematics	Math in school is just calculating, and I can do that.
	Proof-based mathematics	Can I pass the exam now when I can't even do the homework on my own? (...) all those proofs.
	Teaching mathematics	I think we would all be able to teach kids right now.

Research Question 2

In the following, we describe and contrast changes in Values and Expectancy for three selected PST (Greta, Marie, Louisa).

Greta

In the first interview, Greta described high Intrinsic Value as well as Expectancy for procedural mathematics. However, facing proof-based mathematics at the university was very different for her. She described very low Expectancy as well as an absence of Intrinsic Value:

> Greta_1: Now I'm sitting here and realize damn it; the math just isn't working at all at the moment (...) I always found math easy. I've always enjoyed doing math. And then you sit *here*//and *here* it is no fun. (Bea)//

This was related to very high Effort Cost, which she described specifically based on the weekly exercises. Even though she perceived investing a huge amount of effort working on the exercises, this did not pay off for her: "And *here* you think to yourself, I work and work, and still nothing comes of it."

While struggling with proof-based mathematics, Greta still reported high Attainment Value for scientific mathematics. Thus, she wanted to understand the mathematics *here.* However, facing that she mostly did not understand most of the mathematical content, she described a high amount of Psychological Cost, that were related to this Attainment Value:

> Greta_1: I'm also the person who says I have to understand things. (...) I want to understand them. And in math at the moment, at least in LA, it's the case that I don't understand anything anymore. (...) Then the question for me is, do I continue my studies at all? (...) That puts me under complete pressure. I don't know how many times at the weekend I sat at home crying and said, I don't know what to do anymore.

Regarding Attainment Value based on teaching practices, Greta described relatively high Value. She criticized the lack of simple explanations of the mathematics here, indicating she valued them for herself. She also described that she liked the idea of becoming a teacher: "Actually, I would like to do it [studying to become a teacher]". Specifically, the LA course she experienced as rather irrelevant though, for this future career aspiration, describing low content-based Utility Value of LA course:

> Greta_1: Yes, so do I [want to do something with math], but I just want to teach it to people and (…) then I don't really need to do all the stuff in LA.

In the second interview, Greta still described high Intrinsic Value and Expectancy for procedural mathematics:

> Greta_2: Math in school is just calculating, and I can do that. I can also do the stuff in the exercises where you have to do the calculations. That's easy for me, and there's also a certain, yes, sense of joy when I realize that it's working, that it's just going well.

Even though she described slightly higher Expectancy for proof-based mathematics compared to the first interview, her Intrinsic Value for proof-based mathematics remained low:

> Greta_2: Well, I have to be honest, I don't like it [proof-based mathematics] that much better. Sure, I can find my way around it better now. I know how to get to solutions. I know that I have to try different things. So we're slowly becoming friends. Whether we will become best friends, I dare to doubt.

In line with that, she still described high Effort Cost of working on the exercises that took away the joy for her:

Greta_2: And it's constantly stressful just because you're doing math. (…) this constant thought that I have to hand in another math paper next week, and I don't know when I should plan it into my schedule - that just puts me under pressure, and that also takes away a bit of the joy.

While her Attainment Value for teaching remained stable, she described a decrease in her Attainment Value for scientific mathematics:

Greta_2: I don't see myself as a mathematician. For me, it's just the means to an end. So I study math to become a teacher later.

Compared to the first interview, Greta's degree-based Utility Value increased, while she described content-based Utility as further decreased:

Greta_2: I have to be able to do this [referring to the content of the LA II lecture] now until the exam. After the exam, I can safely forget it again.

In conclusion, Greta started mainly objected to procedural mathematics (Intrinsic Value and Expectancy) and teaching (Attainment Value). She had high Effort Cost and very low Intrinsic Value and Expectancy in relation to proof-based mathematics. Even though, she still described a willingness to understand proof-based mathematics and reported high Attainment Value for scientific mathematics. However, her Attainment Value of scientific mathematics had strongly decreased at the second interview, while her degree-based Utility Value increased, indicating a shift to an overall extrinsic motivation.

Marie

Marie started with values and expectations similar to Greta at the first interview. She described high Intrinsic Value and Expectancy for procedural mathematics and rather low Intrinsic Value and Expectancy for proof-based mathematics. She also experienced high Effort Cost working on the exercises:

Marie_1: We are learning here every day, until late at night (…) but no matter how hardworking you are (…) it is extremely difficult.

Like Greta, Marie described high Attainment Value for both objects – teaching and scientific mathematics. In contrast to Greta, though (who wanted to become a *teacher*), she stated that she truly wanted to become a *mathematics* teacher. However, she experienced Psychological Cost, not being recognized as good in mathematics anymore:

Marie_1: It was a bit of an effort to somehow go there [to the tutor] and really reveal, okay, I'm sitting here, I don't understand anything. Because we were all not bad in math at school.

Moreover, she questioned the relevance of the LA course's content, reporting low content-based Utility Value.

In the second interview, Marie reported different Values than Greta. While her procedural Intrinsic Value and Expectancy also remained stable, she described a slight increase in proof-based Expectancy *and* Intrinsic Value:

> Marie_2: For the LA exam, I created a kind of mind map. And in the end it looked quite confused, but somehow it made me very proud and happy.

Furthermore, she did not describe a decrease in Attainment Value for scientific mathematics in the second interview:

> Marie_2: I would really like to be able to say that I am studying to be a teacher, but actually I also feel like a little mathematician.

However, Marie still experienced struggles with understanding and challenges with participating in practices of proof-based mathematics, which was related to high Psychological Cost for her, not being recognized and valued as a mathematician:

> Marie_2: I always felt a bit left out because there was always a line drawn between pure mathematicians [major students] and preservice teachers (…) so you weren't really part of this math community or this math study.

While Marie still described an absence of content-based Utility Value in the second interview, we could not identify any increase in degree-based Utility Value. Concluding, Marie also started highly motivated to become a mathematics teacher, mainly objecting to procedural mathematics. However, her Attainment Value for scientific mathematics remained stable, and her degree-based Utility Value did not increase, in contrast to Greta. Marie described ongoing Psychological Cost, though that seemed to be closely related to her high Attainment Value for scientific mathematics.

Louisa

In contrast to Greta and Marie, Louisa reported somewhat different Values in both interviews. While she also described high Intrinsic Value and Expectancy for procedural mathematics at the first interview, her proof-based Intrinsic Value and Expectancy were higher compared to her peers.

She also described that she had to put much effort into the weekly exercises, but for her, that intensified the joy afterward:

> Louisa_1: And in general, yes, these moments of success are something different than in school. (…) *here*, when something is really good, you are really happy, just because of course you also just put a different effort into it.

In line with Greta and Marie, Louisa also described high Attainment Value for scientific mathematics. However, this was not related to Psychological Cost for her. She stated that she participated "really okay" in mathematical practices and felt valued when chatting with tutors, for example, or communicating about her exercises:

> Louisa_1: Sometimes, I just write something. You know, that it is probably not 100% right, but often I just add my questions to the homework and I was lucky until now that I usually get feedback then.

However, she distanced herself from the teaching job and stated she was unsure if she really wanted to become a teacher, indicating lower Attainment Value for teaching than her peers. Thus, she did not describe any Utility Value for her studies. In the second interview, her Attainment Value for scientific mathematics remained high. Yet, her Attainment Value for teaching had increased, mainly based on the experiences she had during an internship:

> Louisa_2: I would even say that I'm a bit more of a teacher now because of the internship. I feel super comfortable at the school and I really enjoy it and yeah, earlier I was still thinking about whether I really want to do a teaching degree or maybe do something else (…) But I'm really having a lot of fun [at school].

She did still not describe any increase of degree-based or decrease of content-based Utility Value; instead, she distanced herself from statements about the low relevance of mathematical content that she often heard from her peers:

> Louisa_2: Well, you do it [studying mathematics] because you enjoy it. (…) But I think it's a bit like, yes, why do I need this and so. I'll put it this way, I often hear that from the students [in school] now, too. 'Yes, why do I need that and blah, blah, blah.' So you just need it for now, and you'll see [understand] at some point. "

In contrast to her peers, Louisa started highly motivated for her subjects but not teaching. Effort Cost seemed positively related to Intrinsic Value for proof-based mathematics for her. In the second interview, her teaching-related Attainment Value had increased, while she rejected any kind of Utility Value.

Discussion

Our aim was to investigate PST's motivation around different objects of mathematics and teaching. Based on a deductive-inductive approach, we first deductively coded their values and expectancy and inductively identified different objects within these values and expectancy in RQ1 (see Table 2 for the summary). We reconstructed three objects for intrinsic value: procedural mathematics, proof-based mathematics, and teaching mathematics. For attainment value, we reconstructed two objects referring to scientific mathematics and teaching mathematics. Investigating PST's utility value, we found that two different utilities were related to the object of mathematics (as being taught at university): One degree-based utility for passing the exams and getting a degree and one content-based utility for future activities in the teaching job. Regarding cost, the three common dimensions of opportunity, effort, and psychological cost appeared. Opportunity cost was mainly experienced between mathematics and other subjects, effort cost was mainly associated with formal proofs, and psychological cost was often described with the weekly exercises. Expectancy was again discussed relating to the three objects of procedural mathematics, proof-based mathematics, and teaching mathematics.

This study confirmed the findings of Pohlmann and Möller (2010), who differentiated objects of teaching and mathematics, as well as the findings of Ufer et al. (2017), differentiating procedural and proof-based mathematics. We further extended those findings for attainment value. The often-stated utility value of teaching in general (Göller & Besser, 2021, Watt et al., 2012) did not appear in our interviews. However, PST reported perceived contradictions in their utility value for the mathematical content. Those contradiction seem similar to what Hernandez-Martinez and Vos (2018) reported about engineering students, were one dimension of perceived relevance of mathematics was also to obtain grades and finish university. We thus extended their findings for PST and connected them to a SEVT perspective. Regarding cost, only opportunity cost seemed to be related to a specific teaching object, of not having enough time for studying other contents besides mathematics.

In RQ2, we investigated PST's motivational changes in values and expectancy, which differed significantly: Even though two PST started with similar values and expectancy, one showed a decrease in attainment value for scientific mathematics while the other did not. Another PST did not describe any decrease in motivation. We also found different relations between PST's values and expectancy when investigating their motivational development. Intrinsic value and effort cost interplayed in a sensitive relation: demanding situations in mathematics positively affected intrinsic value, while overdemanding situations negatively affected intrinsic value. Furthermore, intrinsic value was related to expectancy. They both referred to the same object and were usually described on similar levels. Another relation was identified between attainment value and psychological cost. Specifically, high attainment value for scientific mathematics was related to high psychological cost for some PST. This seemed to be based on identity tensions, such as not being recognized as a mathematician by other students and faculty staff.

Thus, in contrast to expectations based on quantitative findings (Schnettler et al., 2020), we did not find uniform motivational developments. However, our findings for PST's attainment value development confirm the results that identity development in STEM is closely related to motivational development (Perez et al., 2014). Furthermore, we illustrated the relation between intrinsic value and expectancy that was found in earlier studies (Gaspard et al., 2015; Perez et al., 2019). The positive relation between attainment value and psychological cost that we identified conflicts with current quantitative findings, which usually identify a negative relation (Gaspard et al., 2015). However, this may be based on our specific context of PST, where possibly conflicting identities of mathematics and teaching needed to be negotiated.

Theoretical and practical implications

Our findings address the research gap of the objects of motivation in university mathematics. They support the theoretical considerations by Pohlmann and Möller (2010), as well as Ufer et al. (2017) and Rach et al. (2021) that different objects of values and expectancy can contribute substantially to understanding PST's motivation. While mathematics-specific conceptualizations of motivation often focused on an institutional level of school mathematics and university mathematics (Kosiol et al., 2019; Rach et al., 2021), we extended those findings towards a differentiation on an activity-based level of procedural and proof-based mathematics that seems to be underlying the institutional differentiation. Additionally, we extended this differentiation to all components of SEVT theory. Further explorations of PST's decrease in motivation may thus focus on the three key aspects we identified as objects in mathematics: procedures, proofs, and teaching. In addition, utilities are related to formal requirements and the teaching profession. These objects and utilities are very different in content and their appraisal by PST. Therefore, it seems plausible that the loss of motivation can be traced and explained much more precisely with the help of these aspects, which future research needs to show.

Earlier studies already discussed that some PST's dealing with challenging situations in mathematics might result in an overall "disaffection" with mathematics. This includes the loss of motivation but also distancing themselves from what is valued in scientific mathematics and participating only peripherally (Brown & Macrae, 2005; Gildehaus et al., under review). Our identified relation of attainment value and psychological cost reinforces the assumption that this distancing of oneself from scientific mathematics significantly reduces psychological cost (Göller & Gildehaus, 2021): The decrease in attainment value for scientific mathematics in one of the presented PST may thus have been also some self-care. In contrast, the PST that described no decrease in motivation experienced ongoing psychological cost. It remains unclear whether this decrease is just delayed, based on stronger resilience, or actually released.

Furthermore, the normative question arises in relation to which objects it is desirable to motivate PST. Deep understanding complements procedural knowledge and is a central goal of teacher education. It is an important component of mathematical knowledge, "supporting the development of the ability to deal with contingent moments in the class-room" (Bjerke & Solomon, 2020, p. 692). Furthermore, PST should develop a fundamental appreciation of scientific mathematics (Hoffmann & Even, 2023). However, the interviewed PST here seemed mainly motivated by procedures and easy explanations that they described as relevant to mathematics teaching. Given the perspective of self-care followed by disaffection as discussed above, though, the question arises as to whether this is a consequence of the PST being over demanded. Still, future research, may specifically focus on PST's procedural versus proof-based appreciation.

For practice, we recommend strengthening values and reducing cost. Recently, utility value interventions were repeatedly applied in the field of motivation (Schukajlow et al., 2023), in particular based on profession-related tasks in university mathematics courses for PST (Rach & Schukajlow, 2023). Building on the positive experiences, we suggest: (1) cost-reduction interventions, (2) intrinsic value interventions for proof-based mathematics or (3) attainment value intervention for scientific mathematics. For example, interventions that included reflection on the self helped reduce unpleasant emotions in mathematics, which could reduce cost (Gildehaus & Jenßen, 2023). Identity-based work is highly relevant to increase PST's scientific attainment value. PST may reflect on what is recognized as being mathematical in collaborative groups by negotiating relevant mathematical practices (Rosenzweig et al., 2021). At the same time, faculty staff may also reflect on what they want PST to recognize as mathematical and make transparent what valued practices follow.

PST's descriptions of effort cost when working on proofs, as well as the identified relations to intrinsic value, raise the question of the cases in which obligatory homework may overdemand and demotivate PST and how PST can be supported in this sensitive relation of demanding and overdemanding. Support structures such as mathematics support centers as well as open learning spaces seem relevant here to individually support PST in demanding situations and prevent them from feeling overwhelmed (Lahdenperä et al., 2022; Schürmann et al., 2020).

Strengths and limitations

The empirical, student-centered description of values and expectancy for teaching and mathematics provides new insights into PST's motivation. However, it is also based on very individual perceptions that are strongly based on the social context; here, a German teacher education context with obligatory homework, as well as the specific faculty-staff and PST's wider environment on a somewhat lower level. Unfortunately, for RQ2, we could not follow up with all interviewed PST, which may have prevented us from a broader view of PST's motivational development. Thus, even though we strongly related our results to the theory, they are limited to the given context, and quantitative studies will possibly be needed to generalize the identified objects and relations. However, we provide a promising first insight towards a specific conceptualization of PST's motivation between teaching and mathematics to better understand and foster their motivation in general.

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