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# Epistemological beliefs, motivational values, and study habits among students of tertiary mathematics

Antti Viholainen [1*], Timo Tossavainen [2], Janne Gröhn [1]

[1] Department of Physics and Mathematics, University of Eastern Finland, Campus of Joensuu, FINLAND
[2] Department of Health, Education and Technology, Luleå University of Technology, Luleå, SWEDEN

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**Abstract**

Epistemological beliefs about the nature of mathematics affect how a student perceives mathematics in general, whereas high motivation for mathematics gives an individual a personal reason to study the subject. Epistemological beliefs and achievement motives are quite stable at individual level, but previous research has shown that there are significant differences across students with respect to them. This study concerns university students from three different study programs and investigates relations between the students' epistemological beliefs, motivational values, and study habits. The data were collected using a questionnaire and consist of responses from altogether 98 students studying mathematics courses at tertiary level. The study revealed that, when students are grouped according to their study programs, their motivational values vary across these groups more than their epistemological beliefs. The stability of epistemological beliefs was also verified in this study as the strengths of the beliefs hardly correlated with the number of passed credits or self-evaluated study success. However, several sum variables representing the motivational values and epistemological beliefs seem to predict certain study habits in linear regression models. These models can help us to design the teaching of mathematics courses favouring these study habits.

**Keywords:** epistemological beliefs, motivation, study habits, tertiary mathematics

## INTRODUCTION

Beliefs and motivation have a significant effect on individual's actions. In the case of teaching and learning of mathematics, mathematical beliefs and motivation towards learning have a strong connection to study practices and success. In this study, the focus is on epistemological beliefs about the nature of mathematics (Felbrich et al., 2008) and the motivational values contained in the expectancy-value theory of achievement choices (Wigfield & Eccles, 2000). Epistemological beliefs about the nature of mathematics concern mathematics in general level. They affect how an individual perceives the importance of mathematics, and what is essential in mathematics as a discipline and in learning mathematics. Motivation towards mathematics gives personal reasons to study mathematics: An individual may want to study mathematics because one is interested in it as a subject, because one feels that mathematical skills will be needed later, or because one wants to achieve something. Motivation is also manifested in individual's willingness to make sacrifices, like spending time or other resources. (Wigfield & Eccles, 2000).

One of the long-term objectives in university studies in mathematics is to obtain a deeper understanding about and a broader view on mathematics. Efficient study habits play an essential role in reaching this ultimate goal. This paper is a sequel to the authors' previous article (Tossavainen et al., 2020), where tertiary students' study habits and the use of learning material in university mathematics courses were investigated. The previous study showed that the extent of students' experience from studying in university as well as the local sociomathematical norms (Yackel & Cobb, 1996) have a significant impact on the study habits. The previous study also found significant differences between different student groups. For example, mathematics students without an intention to become a teacher were most traditional in their study habits.


✉ antti.viholainen@uef.fi **(*Correspondence)** ✉ timo.tossavainen@ltu.se ✉ janne.grohn@uef.fi

**Contribution to the literature**

- This study contributes to the literature on epistemological beliefs about mathematics, motivation in terms of the expectancy–value theory, and study habits.
- The study increases understanding about the relations between students' epistemological beliefs, motivation, and study habits, and how these relations can vary across different study programs.
- As well, this study increases understanding about the effects of epistemological beliefs and motivational values on students' study habits in practice. In general, this increases knowledge about the effects of beliefs and motivation on learning.

Interestingly, the participating students' previous performance in upper secondary school did not explain differences in the study habits. In the present paper, the aim is to widen the perspective and to investigate university students' epistemological beliefs and motivational values and their impact on their study habits in learning mathematics. The research questions of the present study are as follows.

1. *How are epistemological beliefs about the nature of mathematics and motivational values in mathematics distributed in among students in different study programs?*
2. *How are these epistemological beliefs and motivational values related to the number of passed credits in university mathematics and students' self-evaluated success in studying mathematics?*
3. *How do these epistemological beliefs and motivational values predict students' study habits in mathematics?*

Knowing students' epistemological beliefs and motivational values gives an advantage in developing better mathematics courses and support for different students. It seems also reasonable to assume that students who have different intentions and goals with respect to their studies may have different epistemological beliefs and different motivational values. This motivates the first research question. The second research question is motivated by the hypothesis that students' epistemological beliefs and motivational values can change under their tertiary education. Although epistemological beliefs and motivational values are slow to change, they are not static, cf. Leatham (2006). The third question is motivated by the fact that both beliefs and motivation have an important effect on an individual's behavior and choices in practical level as the literature in the next section shows.

## Epistemological Beliefs About Nature of Mathematics

Epistemological beliefs are beliefs about the nature of knowledge and learning (Schommer & Walker, 1995). Several studies have shown that epistemological beliefs play a critical role in learning (Schoenfeld, 1983; Op 't Eynde et al., 2006). They affect what is seen important or central in the domain and its learning, and views on how the knowledge is constructed and justified. Schommer and Walker (1995) found that several epistemological beliefs may be domain independent. However, Op 't Eynde et al. (2006) argue based on several studies that is reasonable to separate domain specific epistemological beliefs from general ones. For example, the problem-solving activities are often different in different disciplines.

Viholainen et al. (2014) define, based on the frameworks presented by Ernest (1989) and Felbrich et al. (2008), four orientations related to the epistemic nature of mathematics and its learning. *The formalism-related orientation* means that mathematics is seen as a static system that has been determined beforehand. Instead, according to *the process-related orientation* mathematics is seen rather as an active construction process, where the outcome is not necessarily unambiguous. According to the formalism-related orientation, the learning of mathematics means that the existing mathematical knowledge is understood and internalized, whereas in the process-related orientation acquiring of mathematical reasoning skills and training of creative thinking and problem solving are seen the most central goal. *The scheme-related orientation* means that mathematics is seen as a collection of rules, formulae and calculation methods. The proficient use of these all is seen as a crucial goal of learning in this orientation. *The application-related orientation* emphasizes the connection between mathematics and reality. In this orientation mathematics is seen as a method for describing and modelling different phenomena in the real life and other disciplines. Understanding these connections and development of the ability to apply mathematics in different situations are seen as central learning goals in this orientation.

Epistemological beliefs have an essential effect on what is seen important in learning of mathematics. For example, if the scheme-related orientation (or instrumental view) is strong, it can be assumed that adoption of different skills is seen essential (Beswick, 2005). Furthermore, the formalism-related orientation implies that understanding of the existing and published mathematical knowledge structure is seen as a central goal. Both the scheme- and the formalism-related orientations can be assumed to lead to content-focused learning. Instead, the process-related orientation emphasizes the development of learner's own thinking. According to Beswick, if the learning of mathematics is based on the process-related orientation (or problem solving view), learners' own constructions are valued more than adaptation of existing structures or procedural skills. If the application-related orientation is strong in mind, the value of learning is probably seen depend on how well connections between the content of mathematics and phenomena outside it are understood and how applicable mathematics is seen.

### Expectancy—Value Theory of Motivation

Motivation is a broadly studied theme, especially in the areas of psychology and education. In this article, motivational values applying the framework of the Expectancy–value theory (Wigfield & Eccles, 2000; Wigfield et al., 2009) are studied. According to the original model presented by Eccles et al. (1983), an individual may have expectancies and task values concerning an activity which influence achievement choices, performance, effort and persistence. According to this model, these influences can be explained by individual's ability beliefs and the extent to which one values an activity. With respect to valuation, Eccles et al. define four different components: attainment value, intrinsic value, utility value, and cost.

*The attainment value* means importance on doing well on a given task. The perceived qualities of a task and an individual's need and self-perceptions determine the attainment value for the task. *The intrinsic value* refers to an intrinsic motivation toward the task; it represents interest in and enjoinment from carrying the task. Instead, *the utility value* refers to extrinsic motivation towards a task. It comprises that an individual does not value carrying a task for its own sake but in order to reach something else. *The cost* means the amount of sacrifices that the accomplishment of a task requires. These sacrifices may concern, for example, consumed time, efforts or emotions.

### Research on Study Habits in Mathematics

Research history on study habits is quite long. Already in the 1950s study habits were taken into account in studies on study performance. However, quite often focus was put only on measuring how much time students spend on studying certain contents. By the beginning of the 1970s, also quality of the time spent on studying activities were given more attention (Entwistle, Thompson, & Wilson, 1974).

A significant study on student habits in mathematics courses from the end of the 20th century was made by Cerrito and Levi (1999). They reported that, in principle, students have enough time for learning the content of the courses (students should spend 2–3 hours outside of class studying for every hour they spend in class), but many students choose to spend the reserved time for something else in spite of the fact that regular collection and grading of homework is highly correlated with increased study time in mathematics (ibid.). At the same time, they point out that the sociomathematical norms, especially related to the use of time may remarkably vary between courses and teachers.

Also, Moodaley et al. (2006) have investigated study orientation and causal attribution in mathematics achievement especially focusing on the possible reasons for low achievement in secondary mathematics. Their main findings include that problem-solving behaviour and study milieu have a significant effect on study orientation. A decade later, Thibodeaux et al. (2017) surveyed first-year college students′ time use and its relations with self-regulation and achievement in general, not only in mathematics. They reported that students′ use of their time, both planned and actual academic hours, is directly related to higher self-regulated learning and targetted achievement.

Tossavainen et al. (2020) focused on the students of university mathematics and their study habits and use of learning materials. They noticed that the sociomathematical norms that have a central role in forming the local study culture have also a significant impact on the study habits and how students use textbooks and other learning materials.

All in all, previous research suggests that there are several factors which affect study habits. Time spent on studying plays a significant role but it is not sufficient to explain success in studying.

## MATERIALS AND METHODS

The data were collected from two campuses of a Finnish university during Autumn 2019. A questionnaire was applied, and the data collection was accomplished during one lecture of the chosen first-year- and third-year courses in mathematics. All the participants attending the lecture were invited to participate, yet the participation was not obligatory. Virtually all participated. In the questionnaire, it was explicitly asked whether the respondent agrees that his/her responses are used for research purposes. All participants were adults and no sensitive personal information about them was collected. The responses provided by the participants were treated and preserved confidentially and used for research purposes only as instructed by Finnish National Board on Research Integrity.

Altogether 101 students responded to the questionnaire and all of them, except three, accepted the use of their responses for research purposes. Therefore, N=98 in this study so that 39 respondents (40 %) were studying in the subject teacher education program, 33 (34 %) in the applied physics study program, and 18 (18 %) students in the general science study program. In the lastly mentioned program, the major subject is chosen between mathematics, physics, and chemistry during the first year of studies. Since most science study program students will major in mathematics, this group

**Table 1.** Epistemological beliefs about the nature of mathematics in different student groups

| | | M | SD |
|---|---|---|---|
| Formalism | Teacher education | 3.45 | .72 |
| | Mathematics | 3.61 | .92 |
| | Applied physics | 3.85 | .64 |
| | Total | 3.63 | .75 |
| Schema | Teacher education | 3.21 | .88 |
| | Mathematics | 3.33 | 1.03 |
| | Applied physics | 2.71 | .83 |
| | Total | 3.05 | .92 |
| Process | Teacher education | 3.74 | .60 |
| | Mathematics | 3.75 | .69 |
| | Applied physics | 3.61 | .73 |
| | Total | 3.70 | .66 |
| Application | Teacher education | 3.55 | .73 |
| | Mathematics | 3.64 | .54 |
| | Applied physics | 3.82 | .61 |
| | Total | 3.67 | .66 |

is called ‘mathematics’ in short. Remaining 8 respondents (8 %) were studying in some other study program, and they and the above mentioned three students with unknown study program were excluded from the analyses where the above groups are compared with one another. Hence, in those analyses, N=90 instead of N=98.

In total 55 % of the students had passed 0–12 credits in university mathematics and rests of them 18–120 credits. The first group consists mainly of students from the first-year courses and the latter group from the third-year courses. Altogether 47 % of the respondents reported being female and 51 % being male.

The questionnaire consisted of the following sections:

1. Questions about the educational background of students (study program, number of passed credits in mathematics, some questions about the grades etc.),
2. Eight statements measuring students' beliefs about the nature of mathematics (two statements for each orientation),
2. A choice of a single metaphor to best describe the nature of mathematics,
3. Eight statements on the motivational values toward mathematics (two statements for each value),
4. Fifteen statements on students' study practices,
5. Eleven statements on the use of learning material.

Students were asked to take a stance on the statements on the five-step Likert scale. All relevant questions with the numbering used in the questionnaire are given in the following section when the results are presented. The same questions with minor modifications have been tested and used in several earlier studies (Viholainen et al., 2014; Tossavainen et al., 2017; Tossavainen et al., 2020; Tossavainen et al., 2021; Tossavainen, et al., 2022). For the analyses, sum variables were computed for each type of epistemological belief and each motivational value as the mean of the two corresponding scales.

## RESULTS

### Epistemological Beliefs

The statements measuring the epistemological beliefs about the nature of mathematics are as follows. The sum variables have been computed from the items as indicated in the parentheses.

1. A very important feature of mathematics is that it can be used to describe real world (application).
2. It is not mathematics if it cannot be proved theoretically in an exact way (formalism).
3. Mathematics is a collection of formulas and concepts (schema).
4. Mathematics is solving problems (process).
5. The purpose of mathematics is to maintain functionality in the society and improve people’s life (application).
6. Mathematics is discovering structures and regularities (process).
7. The main task of mathematics is to give the correct rules for calculations (schema).
8. A very important feature of mathematics is that all concepts are defined in a precise and clear way (formalism).

**Table 1** shows the means and standard deviations of the sum variables representing students' epistemological beliefs about the nature of mathematics.

Bonferroni’s post hoc test of Oneway ANOVA revealed some differences between the student groups. With respect to the schema-related orientation, there is a significant difference ($F=3.86$, $p<.05$) between the students of applied physics and mathematics so that the former group has a weaker schema-related orientation than the latter. If the risk level 0.10 is applied, then there also is a significant difference between the student groups with respect to the formalism-related orientation ($F=2.63$, $p<.10$). The highest mean is now related to the students of applied physics and the lowest mean to the group of student teachers.

Concerning the second research question, none of the sum variables measuring epistemological beliefs about the nature of mathematics correlated with the number of passed credits in mathematics. Similarly, if the participating students are divided into three approximately equally large groups with respect to the number of passed credits in mathematics, then Oneway ANOVA did not reveal any significant differences between the groups in any of the sum variables. However, one of the orientations seems to be related to

**Table 2.** Percentage distributions of responses with respect to metaphors describing the nature of mathematics

| Metaphors | Teacher education (n=38) | Mathematics (n=18) | Applied physics (n=30) | Total (n=86) |
|---|---|---|---|---|
| Exact reasoning | 13 | 11 | 13 | 13 |
| Toolbox | 34 | 33 | 30 | 33 |
| Problem solving | 50 | 44 | 33 | 43 |
| Applications | 3 | 11 | 23 | 12 |

the self-evaluated study success; the sum variable representing the schema-related orientation correlated negatively with the variable standing for the self-evaluated study success in university mathematics ($r=-.26$, $p<.05$).

The questionnaire surveyed also which of the following metaphors describes in the best way a respondents' beliefs of the nature of mathematics: *exact reasoning, toolbox, problem solving or applications*. "Exact reasoning" refers to the formalism-related orientation, "toolbox" to the schema-related orientation, and "problem solving" to the process-related orientation. "Applications" refers to itself. Only one option was allowed to be selected. The distributions of responses across the student groups are presented in **Table 2**. They do not differ significantly from one another ($\chi(6) = 7.42$, $p>.05$).

The most popular metaphor was "Problem solving". A half of the student teachers selected this alternative, but among the students of applied physics it was selected only by one third. In all groups, approximately one third selected "Toolbox" and a little bit over one tenth "Exact reasoning". With respect to these metaphors, the differences in proportions between the groups are rather insignificant. However, "Applications" was much more often selected by the students of applied physics than by the student teachers.

## Motivational Values

The statements constituting the sum variables measuring the motivational values are as follows:

11. I really like studying mathematics (intrinsic).
12. I am motivated to study mathematics mostly because it is useful to my other studies (utility).
13. I want to succeed as well as possible in my mathematics studies (attainment).
14. If it is necessary, I would be ready to suspend my hobbies in order to have enough time to prepare myself for exams in mathematics (cost).
15. I am ready to do extra exercises to guarantee that I succeed well in mathematics exam (cost).
16. Even if it was not compulsory, I would study mathematics because everyone in my field must know some mathematics (utility).
17. If I pass a mathematics course with a low grade, I want to take the exam again (attainment).
18. Mathematics is full of interesting problems and results (intrinsic).

**Table 3.** Means and standard deviations of the motivational values in different student groups

| | | M | SD |
|---|---|---|---|
| Attainment | Teacher education | 3.36 | .79 |
| | Mathematics | 3.50 | .73 |
| | Applied physics | 3.55 | .75 |
| | Total | 3.46 | .76 |
| Intrinsic | Teacher education | 3.96 | .67 |
| | Mathematics | 3.72 | 1.11 |
| | Applied physics | 4.33 | .63 |
| | Total | 4.05 | .79 |
| Utility | Teacher education | 3.18 | .83 |
| | Mathematics | 3.42 | .46 |
| | Applied physics | 3.64 | .69 |
| | Total | 3.39 | .74 |
| Cost | Teacher education | 3.30 | .92 |
| | Mathematics | 3.42 | 1.00 |
| | Applied physics | 3.68 | .99 |
| | Total | 3.46 | .97 |

Means and standard deviations of the motivational values are presented in **Table 3**.

The intrinsic value is globally relatively high, which means that, in all the study programs, the students are on average quite well interested in mathematics. However, there is a significant difference between the student groups ($F=4.16$, $p<.05$). The students of applied physics are most interested in mathematics as a subject. Among them the intrinsic-value sum variable was significantly higher than among the subjects from other two study programs ($t=2.67$, $p<.01$). It is also notable that among the students of mathematics there was quite much variation with respect to this value. In the case of the utility value, there was also a significant difference between the groups ($F=3.62$, $p<.05$). The students of applied physics expressed the highest utility value, whereas the student teachers' view of the usefulness of mathematics was lowest. According to Bonferroni's post-hoc test, the difference between these groups is significant ($p<.05$). In general, the cost value varied most among the students.

The answer to the second question was complemented by conducting another series of Pearson correlation analyses and Oneway ANOVAs related to the students' motivational values. None of the sum variables representing the motivational values correlated with the number of passed credits in mathematics at the risk level 0.05. Similarly as in the analyses related to epistemological beliefs above, the participating students were divided into three approximately equally large groups with respect to the number of passed credits in mathematics. These three groups differed from one another with respect to the utility value ($F=4.02$, $p<.05$): the mean of utility value is lowest for the most experienced students and highest for the beginners. Moreover, at the risk level 0.10, these groups differed also with respect to the cost value so that the most experienced students were least willing to make sacrifices for studying mathematics and vice versa. Hence, it is not surprising that there were a negative correlation between the cost value and the number of passed credits at the risk level 0.10 ($r=-.18$, $p<.10$).

Both the intrinsic value ($r=.34$. $p<.01$) and the attainment value ($r=.37$, $p<.001$) correlated positively with the self-evaluated study success in university mathematics. No correlation was found either between the utility value and the study success or between the cost value and the study success.

### Epistemological Beliefs and Motivational Values as Predictors of Study Activities

The participating students' study habits have been reported in more detail in (Tossavainen et al., 2020, p. 262). The same questions are also used in this study:

1. I participate in the lectures of the course.
2. I participate in the small group practicals.
3. I solve exercises before the practicals.
4. I read the lecture material before the lecture.
5. I study the lecture material after the lecture.
6. I ask for help from the lecturer if something about the lecture or the lecture material is unclear to me.
7. I ask for help from my student fellows if something about the lecture or the lecture material is unclear to me.
8. I ask for help from a social media discussion group if something about the lecture or the lecture material is unclear to me.
9. After the practical, I study the correct solution, which we were given at the session.
10. I correct and improve my own solution during the practical.
11. I correct and improve my own solution after the practical.
12. I ask for help from the teacher of practical if something about the exercises is unclear to me.
13. I ask for help from my fellow students if something about the exercises is unclear to me.
14. I ask for help from a social media discussion group if something about the exercises is unclear to me.
15. I spend my time on mathematical hobbies also in my spare time (e.g., programming).

The aim of the third research question was to study how the sum variables measuring students' epistemological beliefs about the nature of mathematics and the sum variables representing their motivational values together might explain students' study habits in mathematics. As listed above, altogether 15 study habits were measured. Four sum variables representing different types of studying activities were computed (as means of the contained items) as follows:

1. Activity to take part in contact teaching (participation activity): 1.1-1.2.
2. Activity to independent studying (independent study activity): 1.3-1.5, 1.9-1.11.
4. Activity to ask questions (questioning activity): 1.6-1.8, 1.12-1.14.
5. Activity to exercise mathematics in spare time (hobby activity): 1.15.

In other words, the sum variable measuring the participation activity is based on the statements 1.1. and 1.2 above, and so on. The independent study activity was measured by six statements where activity to solve exercises independently, activity to study lecture materials before or after lectures and activity to utilize solutions to exercises were asked. The questioning activity includes statements referring to activity to put questions to teachers, fellow students or in discussion groups in internet. The hobby activity consists of only one statement where activity to exercise mathematics in spare time was asked.

A series of linear regression analyses was performed taking these activities as dependent variables and the sum variables representing beliefs and values as predictors. The analyses revealed the following outcomes:

- For the participation activity, the schema-related orientation is the only significant predictor. The dependence between the schema-related orientation and the participation activity is negative ($\beta=-.21$).
- For the independent study activity, the attainment value is the only predictor ($t=3.60$, $p<.01$), and the dependence is positive ($\beta=.35$). If this activity is divided into two parts representing how students prepare themselves before lectures (statements 1.3-1.5) and how actively they study after lectures (statements 1.9-1.11), then the former activity is significantly predicted by the attainment and cost values ($R^2=.20$, $F[2]=11.62$, $p<.001$).
- For the questioning activity, the application-related orientation is the only predictor ($t=3.00$, $p<.01$), and the dependence is positive ($\beta=.29$).
- For the hobby activity, the intrinsic value is the only predictor ($t=3.39$, $p<.01$). The dependence is positive ($\beta=.33$).

These results with their statistical indicators are summarized in **Table 4**.

**Table 4.** Regression models for participation activity, independent study activity, questioning activity, and hobby activity

| Activity | Significant predictor | $R^2$ | df | F | Standardized coefficient | | |
|---|---|---|---|---|---|---|---|
| | | | | | β | t | Sig |
| Participation | Schema | .04 | 1 | 4.23 | -.21 | -2.06 | <.05 |
| Independent study | Attainment | .12 | 1 | 12.96 | .35 | 3.60 | <.01 |
| Questioning | Application | .09 | 1 | 9.01 | .29 | 3.00 | <.01 |
| Hobby | Intrinsic | .11 | 1 | 11.47 | .33 | 3.39 | <.01 |

## DISCUSSION

It can be assumed that the students in each study program form a social community that has its own social norms, valuations, and practices, cf. Tossavainen et al. (2020). These factors may explain many of the observed differences between different student groups. In this study, it was found that the intrinsic value and the utility value were significantly higher among the students of applied physics than among the other students. The entrance requirements are higher in this study program, and the applicants need to compete against each other in order to get in. In addition, the students in this program are probably well aware of the importance of mathematics in their further studies and upcoming work. It is probable that these reasons explain why these students have approximately a higher internal motivation toward mathematics and why they find studying it more useful at a personal level.

The students of applied physics also stand out in several study habits that are associated with efficient study practices (Tossavainen et al., 2020). For example, they expressed that they are very active to participate in teaching and in solving exercises. The high intrinsic and utility values observed above are plausible explanations for these findings, too. High internal motivation for mathematics may also explain, why they had a quite strong formalism-related orientation and a weaker schema-related orientation. Even though these students are majoring in a subject where mathematics is needed merely as a toolbox, it is probable that mathematics has more than an instrumental value for them. Together with high internal motivation, this may help them to make the grade in challenging studies where mathematics plays a crucial role.

The students in teacher education program seem to be somewhat suspicious about the usefulness of the university mathematics for their upcoming work in school. The school mathematics often differs from university mathematics with respect to both content and nature (e.g., Tossavainen & Pehkonen, 2013). This may have an effect especially on the utility value, but also on the intrinsic value among the student teachers. Similarly, the mathematics study program only rarely offers a clear picture of a mathematician's profession and how the courses in university are related to that. Moreover, students in this study program are often more or less unsure about their future career and studies. This may have had a negative effect on their intrinsic and utility values. The high standard deviations in variables concerning epistemological beliefs and motivational values (cf. **Table 1** and **Table 3**) in this group reveal that these students have profoundly various views on mathematics in general. This may be explained by the large variety in students' background in this group: The first-year students in this group had not yet officially chosen their major subject when the data collection was conducted, and, therefore, some of them may later have found more interest in physics, chemistry or other subject than in mathematics. At the same time, this group probably also included upcoming research mathematicians. Also, the amount of experience and study success in mathematics varied a lot in this group; for example, there were a couple of students who had not studied the advanced mathematical syllabus in upper secondary school, which is usually considered a necessary basis for studying tertiary mathematics.

The positive correlations both between the intrinsic value and the study success and between the attainment value and the study success are understandable: if the internal motivation is high, it often leads to a good study success, cf. Wigfield et al. (2009) and Thibodeaux et al. (2017). On the other hand, if high performance is important for a student, it gives a motivation for him/her to invest time and effort in studies. This usually leads to a better study success.

The comparison of results concerning the sum variables about the epistemological beliefs (cf. **Table 1**) and for metaphors presented in **Table 2** raises an interesting question: Why is the toolbox metaphor emphasized over the exact reasoning, although according to the results concerning the sum variables the formalism-related orientation is stronger than schema-related orientation? Most clearly this outcome is seen among the students in the applied physics study program. This may indicate that epistemological beliefs about the nature of mathematics are a multidimensional issue that cannot be captured by a single metaphor in a reliable way.

## CONCLUSIONS

The results of this study indicate that epistemological beliefs are not strongly dependent on students' educational background: Except for the schema-related orientation, no dependencies on the study program, the number of passed credits, or self-evaluated study success were noticed. It is reasonable to conclude that students' beliefs about the nature of mathematics are grounded on personal experiences gained throughout life. Hence, they are to a high degree formed already before students enter a university, and the studies in university do not radically influence on them. Or, at least, the first years in university do not affect them; only a few of students had studied more than three years in university. Therefore, it is valuable to investigate this issue more thoroughly in the forthcoming studies.

One epistemological belief cannot be considered better or more favourable than the others. Instead of trying to steer students' beliefs about mathematics in a specific direction, university mathematics courses should value all aspects of mathematics. If one student sees mathematics first and foremost as a tool to solve problems, the other may appreciate it as a universal language with strict formalism, complicated techniques, and unwavering rigor. However, these beliefs can co-exist, they are not contradictory.

Clear differences between the students in different study programs were revealed, especially with respect to the motivational values. It was also found that the self-evaluated study success in mathematics correlated positively with the intrinsic and attainment motivational values concerning learning of mathematics and negatively with so called toolbox-view of mathematics. This probably indicates that, compared to epistemological beliefs, motivational values are more sensitive to context and situation. This dependency has been observed also in previous studies (e.g., Wigfield et al., 2009).

**Table 4** shows that epistemological beliefs and motivational values predict to some degree students' study habits. For example, the higher the attainment value is, the more actively students are willing to use also independent study habits. However, it is not correct to conclude here that the high attainment value leads to willingness to study alone without collaborating with other students. On the other hand, the negative regression co-efficient in **Table 4** leads us to the conclusion that it is not a good idea to emphasise the schema-orientation too heavily in the teaching of mathematics; it seems that it would lead to a lower participation activity. Another practical conclusion related to **Table 4** is that discussing the applications of the theoretical content of a course can add students' activity to questioning.

The $R^2$-values are not very high in **Table 4**. This does not mean that the models were poor or poorly constructed. The low values only tells that there are also other significant predictors for the predicted variations. This is very typical in educational research; almost every human activity is simultaneously affected by dozens of factors. **Table 4** shows which orientations significantly affect the considered activities, and the conclusion is that these activities are indeed affected by many other factors, too. Hence this topic deserves to be studied further.

All in all, a general conclusion of this research is that students with high inner motivation are prone to use those study habits which are associated with efficient study practices. Also, the large variation of epistemological beliefs observed in this study indicate that students are, despite all well-known challenges related to studying university mathematics, provided with a versatile view of mathematics. Moreover, as study habits are not determined by any single orientation to mathematics, a conclusion is that efficient study practices can be developed regardless of what kind of mathematics is studied (e.g., applied or pure mathematics).

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**Data sharing statement:** Data supporting the findings and conclusions are available upon request from the corresponding author.

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