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ORIGINAL PAPER

Components of task values in a university mathematics course: trends, fluctuations, and relations to individual characteristics

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Abstract

According to situated expectancy-value models, task values are important in mathematical learning processes. In university mathematics courses, some students devalue the mathematical content. To gain more insight into students' task values during mathematics lectures, we analyzed the fluctuations of different task value components within and between lessons in a first-semester lecture in relation to individual characteristics. The participants in our study were 181 university mathematics students enrolled in a teacher education program. They reported their intrinsic value, attainment value, utility value for the study program, and utility value for professional life thrice in each lesson, for four lessons over one semester. At the beginning of the course, they reported individual characteristics. The results of variance decompositions and correlational analyses indicated that almost all task value components differ only marginally between lessons and time points, but substantially between students. We found strong correlations between interest in university mathematics and intrinsic and attainment values. We discuss our findings with regard to different task value components.

Keywords Components of task values · Decomposition of variances · Pre-service teachers · Task values · University mathematics program

1 Introduction

Imagine a university student is asked to rate statements like "This lecture was quite enjoyable" and "This content was rather relevant for my further life". If the student provides different ratings at various points during a lesson or semester, it reflects that they value the content differently depending on the context (Dietrich et al., 2017). This is important because the identification of the situations relevant for students allows teachers to better adapt the teaching process to students' value beliefs. For example, this enables the integration of concrete applications of mathematical concepts that students report as relevant into lectures. Subjective task values refer to learners' perceptions of a task and is part of (situated) expectancy-value models (Eccles & Wigfield, 2020). In the present study, we investigated if university students report different enjoyment of content (intrinsic value), personal importance of content (attainment value), and ascribed relevance of content for current and future aims (utility value) in different situations. Concretely, we focused on intraindividual variations in task values and examined how the various characteristics of these variations are associated with other individual characteristics.

The study's context was university mathematics learning, particularly in the study entry phase, where many students drop out of their study program (Geisler et al., 2023b). Considering that university students choose their study program, it is reasonable to expect that they may report high task values. However, first, students differ substantially in their motivations (e.g., Ufer et al., 2017). Second, students also report learning opportunities that they value very much, such as preparatory courses, and opportunities that they do not value, such as working on homework and participating in lectures (Büdenbender-Kuklinski et al., 2024; Geisler et al., 2023a). Third, the evaluation of these learning opportunities differs between students, which may owe to different

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learning backgrounds, such as prior achievements (Benden & Lauermann, 2022).

In their overview article of the special issue "Situational impact on Learning and Instruction", Pekrun and Marsh (2022) summarized the development of theories and the often-used methodological paradigms to identify current progress and open questions on research on situated emotion and motivation. As a base of their considerations, they define the term "situation" as "the term can be used to denote different points in time or different types of contexts" (Pekrun & Marsh, 2022, p. 2). This implies that situational variations in motivation can be examined with respect to time and context. In their overview, they adopt an educational psychologist's perspective and pay little attention to learning processes within a specific subject. In contrast, we focus on a mathematics-specific phenomenon: pre-service students' low valuation of university mathematics.

Specifically, we examined moment-to-moment variations in task values in a first-semester mathematics lecture, which addresses the time- and context-specificity of task values. In a previous analysis of the project "Situational Interest in a Mathematics study program" (SIMs), we surveyed 181 undergraduate students who reported on their task values and effort three times in four different lessons. In that analysis, we treated task values as a joint scale and focused on, for example, the prediction of effort by task values (Rach, 2023). Current studies, for example, Parrisius et al. (2022) and Sutter et al. (2024), present distinct patterns in the time-specificity of intrinsic value and indicate that it is worthwhile to analyze the components of task value separately. Thus, in the present study, we decompose task value components by time point and person, investigate value component trends across the semester, and variations within lessons, each related to individual characteristics. The goal was to clarify the structure of task values, particularly inter- and intraindividual differences in task value components among first-semester mathematics students.

2 Theoretical and empirical background

2.1 Teaching and learning mathematics at university

Considering the many reports of substantial learning difficulties amid the transition from mathematics learning at school to university, this can be considered a major transition point in mathematics learning from the perspective of students. Many studies assume that the difficulties stem mainly from differences between school and university regarding mathematics teaching and learning. Specifically, while school lessons primarily deal with informal representations of mathematical concepts, such as examples or visual representations, and schematic calculations, university instruction focuses on building a mathematical theory based on formal definitions of concepts and proofs of statements (Umgelter & Geisler, 2024; Weber et al., 2023). The teaching process changes from a lesson-based system in school to a lecture-tutorial-self-study system at university (Montecino & Andrade-Molina, 2024). At universities, mathematics lectures presenting new content are often held in a definition-theorem-proof format for all students in a study program (Bergsten, 2007). In tutorials, tasks from exercise sheets on which students worked before tutorial onset are discussed in smaller student groups (Weber et al., 2023).

Wasserman et al. (2023) provide an informative overview of university mathematics in secondary teacher education programs. Pre-service teacher students have clearer career goals than students in many other study programs. In a nutshell, students in teacher education programs are often confronted with the high demands of mathematical university courses but may perceive such courses to be of low relevance for their future profession (Büdenbender-Kuklinski et al., 2024; Eichler & Isaev, 2023; Weber et al., 2023). Moreover, students in a teacher education program may perceive themselves as less connected to mathematics than major students (Gildehaus et al., 2024a; Guse et al., 2023). These two observations relate to students' utility value and attainment value concerning mathematics courses.

2.2 Task value components: conceptualization and operationalization

Subjective task values are part of (situated) expectancy-value models, which attempt to explain learners' choices and achievements in learning processes (Eccles & Wigfield, 2020). Task values, referring to learners' perceptions of a task, can be divided into four components, namely intrinsic, attainment, utility value, and costs. Intrinsic value is conceptualized "as the anticipated enjoyment one expects to gain from doing the task for purposes of making choices and as the enjoyment one gets when doing the task" (Eccles & Wigfield, 2020, p. 4). This component is similar to the feeling-related facet of interest and intrinsic motivation, and refers to actions performed in the learning process. Attainment value is referred to "as the relative personal/identity-based importance attached by individuals to engage in various tasks or activities" (Eccles & Wigfield, 2020, p. 5). Gaspard et al. (2015) and other researchers, meanwhile, consider attainment value to also be related to the importance afforded to achievement, especially as the outcome of engagement. Utility value is conceptualized as "how well a particular task fits into an individual's present or future plans" (Eccles & Wigfield, 2020, p. 5), and it connects the self and the consequences of a learning action, hence being related to extrinsic motivation. Gaspard et al. (2015), who developed and validated an extensive questionnaire to measure task value

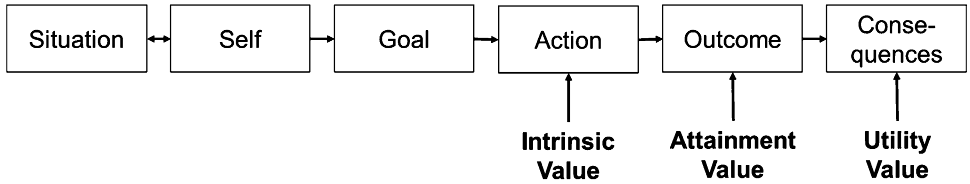

Fig. 1 Task values in the learning process, adapted from Urhahne and Wijnia (2023, p. 7)

components in secondary mathematics classrooms, divided utility value into different facets to explicitly focus on goals in social, professional, and everyday contexts. Moreover, the construct of costs expresses negative aspects when dealing with tasks. Some scholars regard this construct as an additional part of expectancy-value models (e.g., Barron & Hulleman, 2015), as one can consider different mechanisms concerning the role of value and costs in successful learning processes. Therefore, we omitted costs in this study and focused on values as the positive aspects of dealing with tasks.

To provide a visual framework for motivational theories, Urhahne and Wijnia (2023) proposed a linear basic model and integrated task values into this model (Fig. 1). In their article, they compared different motivational theories with a focus on their similarities and differences. We highlight especially interest theory, which defined individual interest as a construct that "represents a more or less enduring specific relationship between a person and an object in his or her 'life-space"' (Krapp, 2002, p. 387). Meanwhile, Urhahne and Wijnia (2023, p. 15) proposed individual interest as a "fixed characteristic of the self", independent of a specific content. Importantly, individual interest is often treated as a trait-like individual characteristic, involving being yet more developed and less changeable. Renninger and Hidi (2011) proposed a process model of interest development that goes from situational interest (i.e., state-like characteristic based on the situation) occasions to the development of individual interest. Situational interest and task values have many common features, including situation dependency and the incorporation of positive emotions.

To deepen our understanding of task values in a university mathematics course, we mapped the theoretical model in Fig. 1 to mathematics lectures. Specifically, in this study, intrinsic value is the enjoyment of listening to the lecturer and trying to understand the content (e.g., "This lecture was quite enjoyable"). Attainment value focuses on action outcome (e.g., content understanding), whereas utility value refers to the consequences (e.g., "This content was rather relevant for my further life"). In university study programs, the consequences can be passing exams (as a near goal) or becoming competent in a profession (as a later goal).

2.3 Task values in mathematical learning processes: relation to individual characteristics and situation-specificity

2.3.1 Task value variations by situation and individual

Törmänen et al. (2025) summarized studies on moment-to-moment changes in motivation across age groups, affording evidence of inter- and intraindividual differences in learners' situation-specific motivation. The following paragraphs will mainly focus on studies that analyzed task value components in mathematics or higher education learning processes.

Across 10 lessons of an educational psychology course, Dietrich et al. (2017) asked three times a lesson, 155 preservice teachers to rate their task values. With this design, they can distinguish task values by topic (each lesson covers a different topic) and by the time point within each lesson. Thus, it is possible to explore long-term changes in task values by analyzing them across the entire course, and short-term changes by analyzing them within a single lesson. Owing to the nested structure of their data, they conducted multilevel analyses. At each level, specific learning situations, topics, and students exhibited substantial task value variability. Sutter et al. (2024) measured the task values of 219 undergraduate students in an introductory statistics course. Students rated the value components at the beginning of each topic for 10 weeks; they found variability in utility value by situation and individual of comparable sizes, whereas intrinsic value (measured similarly to situational interest) varied more strongly by individual than by situation. In five consecutive mathematics lessons in ninth grade, Parrisius et al. (2022) measured 1,617 students' value components, using a composite scale of attainment and utility value termed importance. Most of the variance in importance was a function of time-consistent components rather than fluctuating components, whereas for intrinsic value, fluctuating factors were the predominant source of variance. This is contrary to the findings in the study by Sutter et al. (2024), where there was more variance within students than between students for intrinsic value.

2.3.2 Relation between task value and individual characteristics

In the study by Rach and Schukajlow (2023), 133 preservice mathematics teachers reported their interest in school mathematics, and their task-value components for seven mathematical tasks from number theory. For example, they found that interest in school mathematics, which is relatively stable during a first-semester mathematics course (see Kirsten et al., 2025), relates to intrinsic value, attainment value, and utility value for professional life to a small extent. Based on the findings in the study by Rach and Schukajlow (2023) and the definitions we provide in Sect. 2.2, we assume that task values in a mathematics situation relate to individual interest in mathematics as an individual trait. Then, since individual interest in university mathematics seems to relate to task values, and mathematics students reported a higher interest in university mathematics than pre-service teachers (Ufer et al., 2017), one can conclude that value components regarding university mathematics differ between study programs in favor of mathematics students.

Concerning gender, Gaspard et al. (2015) showed, in 82 ninth-grade mathematics classes, that female students (vs. male students) reported lower intrinsic value, attainment value (only in individual importance as a subdomain), and utility value for future life and for jobs. In contrast, Høgheim and Reber (2019) could not identify differences among 366 male and female middle-school students regarding situational interest concerning mathematics, but they did find differences in individual interest. Benden and Lauermann (2022, 2023) used an intensive longitudinal design to analyze the data of 1,004 first-semester students in mathematics-intensive study programs, including physics, mathematics, and mathematics teacher education programs. The items for course-specific value beliefs focused on the object "coursework and assignments". Considering grade point average (GPA) as an indicator of prior achievement, Benden and Lauermann (2022) indicated that students' GPA was positively related to their baseline intrinsic and utility value in coursework and assignments. However, the relation between GPA and task value components at the end of the course remained unclear. Contrasting the findings by Benden and Lauermann (2022), Fryer et al. (2025) conducted a study in a mandatory teaching course for research postgraduate students. 415 students reported their prior knowledge at the beginning of the course and their course interest four times in the course. Unexpectedly, prior knowledge was negatively related to the intercept of course interest, which may be grounded in the introductory nature of the course: students with a high prior knowledge may feel there is nothing to learn in this course.

2.3.3 Task value trends

Benden and Lauermann (2022) found that students' intrinsic and utility values declined during the semester in a mathematics course—for similar results for utility value in an introductory psychology course, see the study by Kosovich et al. (2017)—and that there was a substantial change in students' value beliefs during weeks two and three. Female students and students with comparatively lower GPAs showed a substantial decrease in intrinsic value (Benden & Lauermann, 2022). Moreover, a decrease in intrinsic and utility value, mainly in the initial part of the course, was reported by Sutter et al. (2024) in the context of an introductory statistics course. Fryer et al. (2025) found that prior domain interest is negatively related to the slope of course interest.

Asada et al. (2024) interviewed six students enrolled in an abstract algebra course about their value beliefs. They reported adjustment processes regarding task values. Some students realized that the course's specific content may not be helpful in their professional field, but they nevertheless liked some of it. According to this study, after an initial phase, students decide whether the contents of a university program are relevant for their later profession (utility value), and whether knowing a lot about the contents is important for their identity (e.g., as a teacher; attainment value). These evaluations tend to be relatively long-lasting, and the two value components do not change significantly. The interview study by Asada et al. (2024), therefore, supports the notion that task value component trends differ between students. A mechanism to explain interindividual differences in intrinsic value changes is as follows: if students relate enjoying the action to the outcome and to the consequences of the action, that means that intrinsic value relates to attainment and utility value, and hence intrinsic value will change similarly to the other two components of task values—that is, it will change only slightly. If students focus on listening and trying to understand the content without considering the outcome and consequences, intrinsic value will change more than the other two components.

As many pre-service teachers question the relevance of university mathematics for their later professional lives (Weber et al., 2023), related interventions have aimed to connect university to school mathematics to obtain a split-over effect, in hopes that this would enlighten the relevance of university mathematics for school mathematics teaching (Eichler & Isaev, 2023; McGuffey et al., 2019; Rach & Schukajlow, 2023). These interventions primarily focus on learners' utility value (Rosenzweig et al., 2022). Still, studies in other mathematical contexts, such as secondary schools, have shown that interventions focusing on utility value can also influence other task value components, such as intrinsic value (Parrisius et al., 2020). Such interventions to foster students' value beliefs are helpful only if students ascribe different values to different learning situations or contents. A recent review of 35 studies by Guo and Fryer (2025) focused on value-focused interventions, identifying six sources that stimulate situational interest (a construct similar to task value); among the 35 reviewed studies, 14 were conducted at the undergraduate level and seven dealt with mathematics. These identified sources (utility value, novelty, cognitive activation, social interaction, hands-on activity, and choice) relate to learning environment features.

2.3.4 Task value short-term fluctuation

In previous studies, experience sampling approaches were applied to analyze fluctuations in motivational constructs. To the best of our knowledge, only a few studies have analyzed the task value short-term fluctuations in one lesson. In a follow-up analysis to the aforementioned study by Dietrich et al. (2017), Moeller et al. (2022) split the task value scale into different components and analyzed fluctuation in one lesson. For intrinsic, attainment, and utility value, there was no significant autoregression from one learning situation to the next, and intraclass correlations in all components were higher for time points in a lesson than for time points between lessons and individuals. These results indicate a substantial fluctuation in task value components within an educational psychology course lesson.

3 The present study

Previous studies have shown that task values are essential to mathematical learning processes in universities (e.g., Benden & Lauermann, 2022). The learning processes in universities are generally situated in lectures, tutorials, and self-study phases, accompanied by working on mathematics tasks. Whereas Benden and Lauermann (2022, 2023) focused on intrinsic and utility values related to tutorials and tasks, we examined intrinsic, attainment, and utility values perceived in a lecture. As we assumed that many of our participants would be students in a teacher education program, we split utility value into utility value for the study program (i.e., for near goals) and utility value for professional life (i.e., for later goals). Like Dietrich et al. (2017), we used an intensive longitudinal design to measure task value components (attainment value, intrinsic value, utility value for the study program, and utility value for professional life) three times across four lessons in a university lecture course. With this design, we can analyze trends in task value components over one semester (long-term changes) and fluctuations within a single lesson (short-term changes). At the beginning of the course, the following individual characteristics were measured: interest in school mathematics, interest in university mathematics, study program, gender, and general prior achievement by grade. The following research questions guided our examination of intraindividual differences in task value components and their possible associations with individual characteristics:

1. *Decomposition of the variances in task value components*: how much of the variance in task value components is explained by the time point in the lesson, the time point of the lesson during the semester, the individual, and the interactions between them?

   Hypotheses: we assumed that attainment and utility values depend strongly on the individual and less on the specific lesson, whereas intrinsic value depends on the individual and the specific lessons (see Dietrich et al., 2017; Parrisius et al., 2022; Sutter et al., 2024). We assumed a low-variance explanation for all components within a lesson. We had no specific hypotheses for interactions between individuals and time points.
2. *Relation of task value components with individual characteristics*: how do task value components relate to individual characteristics?

   Hypotheses: we expected task value components to be strongly related to interest in university mathematics and not school mathematics because university lecture contents pertain to university mathematics. In addition, mathematics students show more beneficial value than pre-service teachers (Ufer et al., 2017). We expected no substantial relations of task values with gender or prior achievement (see Benden & Lauermann, 2022; Fryer et al., 2025; Høgheim & Reber, 2019).
3. *Task value component trends and their relations to individual characteristics*: how do task value components change during the semester? How do individual characteristics relate to this change?

   Hypothesis: we expected a negative trend in attainment, intrinsic, and utility values for most students (Benden & Lauermann, 2022). This change is to be observed particularly among students in teacher education programs and those with a low interest in university mathematics. We expected no substantial relations of task value component trends with interest in school mathematics, gender, or prior achievement.
4. *Task value component fluctuations within lessons and their relations to individual characteristics*: how consistent are task value components from one moment to another within one lesson of a university lecture? How do individual characteristics relate to these task value component fluctuations?

   Hypotheses: we had no hypotheses regarding which task value component would be more consistent in a lesson. We expected the utility value of mathematics students to fluctuate more in a lesson than that of pre-service teachers because mathematics students' future professional fields are not fixed. We also expected prior achievement to be related to task value component fluctuations because of the following mechanism: students with higher prior achievement can perceive different content more effectively than those with lower prior achievement. Different content perceptions lead to different ascriptions of task values.

4 Methods

4.1 Sample

The study was conducted with 181 participating students from an undergraduate mathematics program at a German university (age: M= 19.6, SD = 2.0 years; 94 male, 56 female, 31 no information); most (n= 131) were in their first semester. Students reported their final school qualification grade from 1.0 (very good) to 4.0 (sufficient), M = 2.35; SD = 0.61; N = 145, and their mathematics grade from 15 (very good) to 0 (insufficient), M = 10.98; SD = 2.58; N = 140; the final grade is a well-known indicator of prior achievement (Trapmann et al., 2007).

Data on age, gender, and study program were missing for some students who were not present at the first measurement. We informed the students about the project's aims, funding agency, and design. Students knew that we would ask about their motivation in four lessons throughout the semester, and that we conducted this project to support students studying mathematics. In addition, they received an information sheet on the data-saving procedure and data security. In total, at most 5% of the students did not agree to participate in this study. Students had the opportunity to ask questions about the survey, provided informed consent, and voluntarily participated in this study in all four lessons; no human subject approval for the present research was required by the institution's ethics review board. Most students were enrolled in a teacher education program that included mathematics (59 male, 49 female), and the remaining students were enrolled in a bachelor's mathematics program (13 male, 7 female) or another STEM study program (22 male, 0 female). Students in the mathematics teacher education program participated together with mathematics students in many courses during their first year of study. Data was collected during a lecture for first-semester students dealing with linear algebra.

4.2 Design

The lecture was structured as a typical lecture at a German university, comprising 14 weekly sessions, each lasting 90 minutes, conducted from October to January. A university professor of mathematics held the lecture. We collected our data in four lessons: at the beginning of the semester (October), in its fourth week (November), seventh week (December), and twelfth week (January). Within these four sessions, students were asked to report their task values in paper-and-pencil questionnaires at three time points, as described herein: after 15, 45, and 75 minutes (see Fig. 2). Using this design, the time between two measurement points is not equal but varies between 30 minutes and five weeks.

At face value, the teaching format was the same in the four lessons we conducted; the lecturer explained the learning content and recorded definitions, theorems, proofs, among others on a blackboard. A more in-depth analysis allowed us to note that the lessons changed in the specific content that the students had to learn. In the lesson in October, the lecturer presented important statements concerning injective and surjective functions. In the lessons in November and December, fields and matrices were central. In January, the lecturer applied the mathematical content to realistic situations in computer science.

Content presentation and motivation also changed in each lesson, in line with the change in learning content. In the lesson in October, the lecturer highlighted the importance of the presented content for mathematical and realistic issues. In the lesson in November, the lecturer asked mathematical questions upon which students had to ponder about, mainly in the first part (in the first 15 minutes) and second part (in the first half of the lecture, Fig. 2); in the third part, the lecturer only wrote information on the blackboard. In the lesson in December, the lecturer attempted to visualize mathematical information by referring to a card game and explaining its mathematical structure. In the lesson in January, the lecturer gave an anecdote about the establishment of a big IT company. The fact that the methods in the lessons did not change substantially is less critical for the study because the statements concerning task values refer to the content.

4.3 Measures

In this study, we used questionnaires adapted from Linnenbrink-Garcia et al. (2013) and Dietrich et al. (2017) to assess task value components (see Törmänen et al., 2025). The use of single-item indicators was a deliberate design choice to minimize disruption of ongoing instruction and to allow repeated in-lesson assessment. Prior works, for example, Gogol et al., 2014 and Sutter et al., 2024, show that single-item measures can be acceptable for narrow, clearly defined constructs in intensive or classroom-based designs, particularly when items are adapted from a validated multi-item scale (see also Nuutila et al., 2018).

Each time, a trained mathematics educator signaled to complete the questionnaire. Students were asked to consider the content of the past couple of minutes and complete the questionnaire within three minutes (Dietrich et al., 2017). The complete items are listed in Table 1. Participants rated each item on a four-point Likert scale ranging from 1 (disagree) to 4 (agree).

All items focused on content because there is content in every lesson, and the items used in experience sampling studies must fit numerous situations (Horstmann & Ziegler, 2020). The item measuring intrinsic value focused on content enjoyment. The item for measuring attainment value combined both facets of attainment value; because knowledge is a part of someone, the item touches the individual's

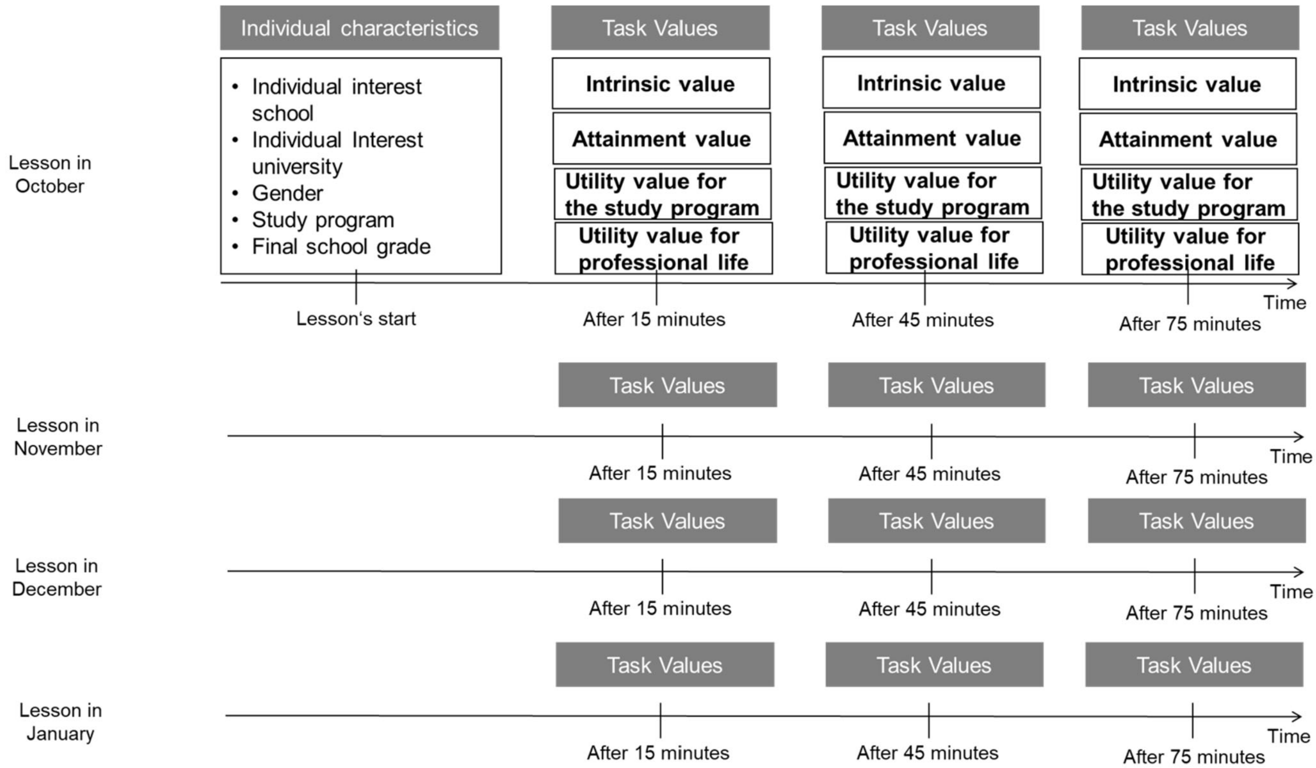

Fig. 2 Design of the study

Table 1 Task values measure

	The following statements pertain to the lecture *contents of the last couple of minutes*. Please rate each statement.	Die folgenden Aussagen beziehen sich auf die *Vorlesungsinhalte der letzten Minuten*. Kreuzen Sie bitte jeweils an.
Intrinsic value	I like these contents.	Ich mag diese Inhalte.
Attainment value	It is important to me to know much about the contents.	Mir ist es wichtig, über diese Inhalte viel zu wissen.
Utility value for the study program	The contents are important for my study.	Diese Inhalte sind für mein Studium wichtig.
Utility value for professional life	The contents are important for my future career.	Diese Inhalte sind für mein Berufsleben wichtig.

Note: Ad-hoc translations and original items in German

identity, and knowing much about something probably leads to success. Utility value was split into two facets: concerning the study program (near goals) and professional life (far goals).

We used established questionnaires developed and validated in other studies and projects (see Geisler et al., 2023b) to measure individual interest. In the project SISMa, Ufer et al. (2017) developed an instrument that differentiated between individual interest in school and university mathematics. A sample item for interest in school mathematics was "I am interested in the kind of mathematics that I learned at school." They used similar items for university mathematics but replaced "school" with "university." Students rated all items on a four-point Likert scale ranging from 1 (disagree) to 4 (agree). The mean scores for all the scales were computed for valid responses (i.e., more than half of the items had a valid response). An exploratory factor analysis, conducted in R using the package "psych" and assuming two components, indicated that the items loaded on the specified components: five items loaded onto the component representing interest in school mathematics, with loadings ranging from .43 to .76, and five items loaded onto the component representing interest in university, with loadings ranging from .64 to .79. The absolute values of cross-loadings were smaller than .23, except for one item measuring interest in school mathematics, which had a cross-loading of .32. The scales showed sufficient consistency, as follows: interest in school mathematics, n= 147, Cronbach's α = .74; interest in university mathematics, $n = 149$, Cronbach's $\alpha = .81$. The means and standard deviations are shown in Table 2, and the correlations in Table 3.

4.4 Analysis strategy

In this study, we focused on different task value components and used various measures to analyze their fluctuations.[1] As is typical of intensive longitudinal studies, data were missing at several levels. There were data missing both for single time points and lessons. All available data were used in the analysis without specific missing data treatment such as filling in missing values with plausible values.

To analyze the differential contributions of time points within lessons and between lessons, individuals, and their interactions, we performed ANOVA including three main effects and four interaction effects. We computed the "percentage variance explained" per effect from the sum of squares. A graphical representation of the results is shown in Fig. 4.

For all four task value components, we obtained three characteristic fluctuation measures: (i) the mean of observations across lessons; (ii) the trend of observations across lessons; (iii) the standard deviation of observations within lessons. We considered the empirical mean across a student's lesson means (i.e., the three means across a student's observations in a lesson) as the student's mean. Their trends were obtained by performing a regression of the students' lesson means on the lesson number. The students' standard deviation within lessons was obtained as the empirical standard deviation of all their lesson-mean-centered observations. By lesson-mean-centered, we mean that we removed the lesson means from their observations so that the variability between lessons was removed and thus not part of the measure. All three fluctuation measures are shown in Fig. 3, along with the conceived data. After calculating these measures for all task value components, we subjected them to a series of analyses. The analyses included (a) the calculation of distributional characteristics across students (e.g., mean and standard deviation) and (b) calculations of correlations and t-tests to analyze the relations among the measures and with individual characteristics.

5 Results

Table 2 provides a descriptive overview of the data. No floor or ceiling effects were observed.

5.1 Variance decomposition of task value components

Figure 4 shows how the time points, students, and their interactions explain task value component variances. The size of the visualized area represents the variance explained by the variable, and if the area is almost impossible to recognize, this variable explains nearly no variance.

The time point of the lesson and the time point in the lesson explained only a marginal amount of the variance in intrinsic value, attainment value, and utility value for professional life. Regarding utility value for the study program, the time point of the lesson during the semester explained 12% of the variance. All task value components varied substantially between students, as indicated in Fig. 4 by the term STUD: intrinsic value (57%), attainment value (61%), utility value for the study program (42%), and utility value for professional life (59%). The interactions by time points and students indicated that students differed in how strongly the value components changed across time points.

5.2 Relations of task value components with individual characteristics

Table 3 shows all correlations between the fluctuation measures for all four task value components and individual characteristics. As expected, interest in university mathematics correlated strongly with intrinsic value ($r = .66$) and utility value for professional life ($r = .49$) and at a medium level with attainment value ($r = .35$). Female students showed lower intrinsic value ($r = -.20$) than male students. Moreover, t-tests indicated that mathematics students reported higher intrinsic value (*Estimate* = 0.72, $SE = 0.15$, $p < .001$), attainment value (*Estimate* = 0.91, $SE = 0.18$, $p < .001$), utility value for the study program (*Estimate* = 0.35, $SE = 0.13$, $p < .01$), and utility value for professional life (*Estimate* = 0.64, $SE = 0.16$, $p < .001$) than pre-service mathematics teachers. No further relations between task value components and individual characteristics, for example, interest facets, were significant.

5.3 Task value component trends and their relations to individual characteristics

There was a negative trend in all four task value components during the semester (Table 2), albeit generally small. This trend was the highest for utility value for the study program (mean = -0.17). Only interest in university math-

[1] Results for the joint scale task values using linear mixed models and the same data set from the project SIMs can be found in Rach (2023). Rach (2023) examined the situation-specificity of task values as a holistic scale, the prediction of task values by individual characteristics and the fulfillment of basic needs, and the prediction of effort by individual characteristics and task values.

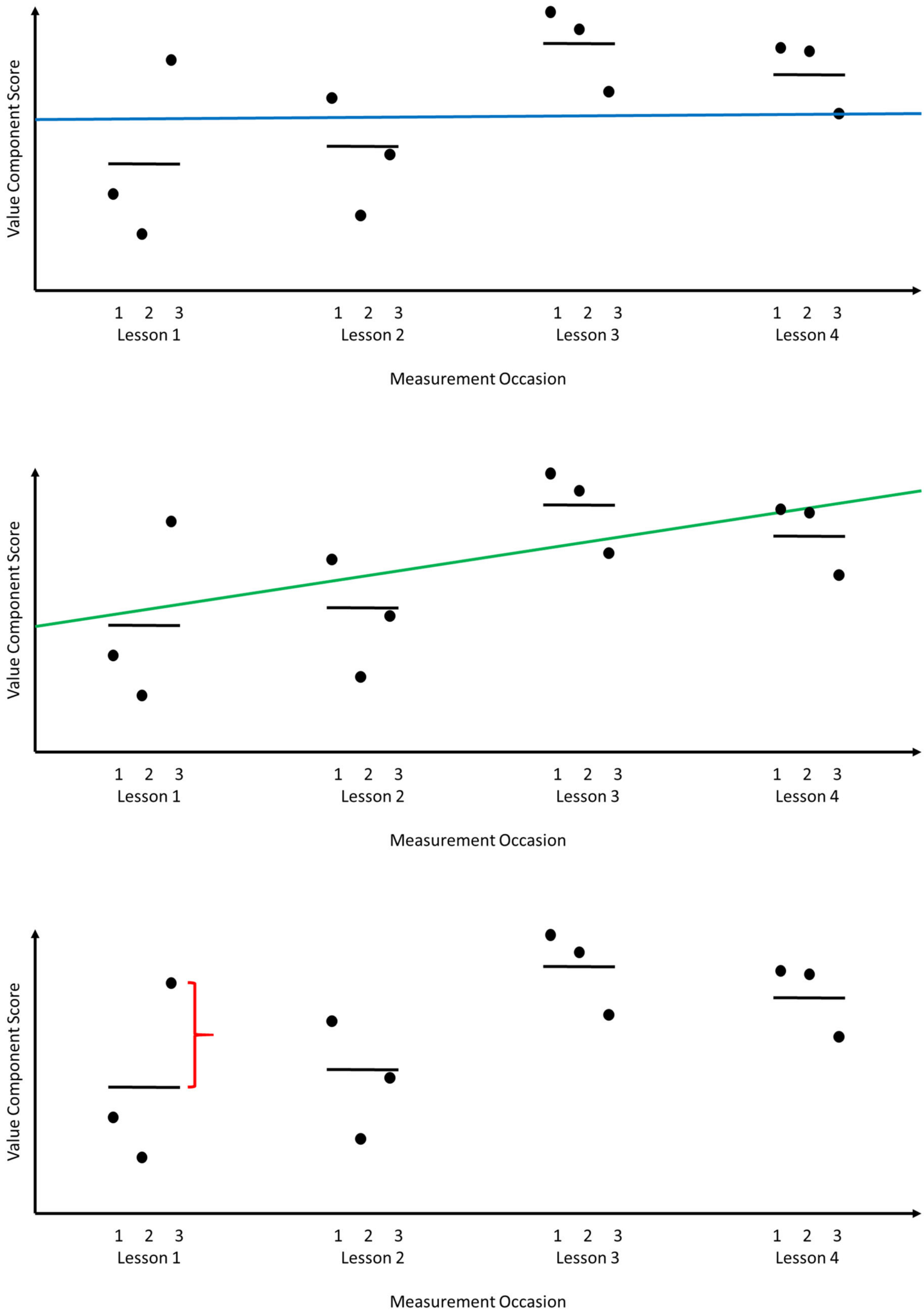

Fig. 3 Three characteristic fluctuation measures. The upper panel shows the mean of observations across lessons. The middle panel presents the trend of observations across lessons. The lower panel presents the standard deviation of observations within lessons

Table 2 Means, standard deviations, and number of participants for each study variable

		M	*SD*	*n*
Mean of observations across lessons	Intrinsic value	2.68	0.70	183
	Attainment value	2.21	0.80	182
	UV study program	3.23	0.59	183
	UV professional life	2.73	0.72	183
Trend of observations across lessons	Intrinsic value	-0.02	0.33	103
	Attainment value	-0.05	0.40	102
	UV study program	-0.17	0.31	102
	UV professional life	-0.11	0.32	102
Standard deviation of observations within lessons	Intrinsic value	0.43	0.31	183
	Attainment value	0.32	0.32	182
	UV study program	0.37	0.35	183
	UV professional life	0.37	0.32	183
Interest in school mathematics		2.90	0.55	150
Interest in university mathematics		2.57	0.59	149
Final school grade		2.35	0.61	145

Note: UV: utility value. Items for measuring task values and interest facets were rated on a four-point Likert scale ranging from 1 (disagree) to 4 (agree), and final school grade ranged from 1.0 (very good) to 4.0 (sufficient)

Table 3 Correlations of the study variables

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
01 MOL Intrinsic value	-	182	183	183	103	102	102	102	183	182	183	183	150	149	145	150
02 MOL Attainment value	**.50**	-	182	182	102	102	102	102	182	182	182	182	149	148	144	149
03 MOL UV study program	**.22**	**.33**	-	183	103	102	102	102	183	182	183	183	150	149	145	150
04 MOL UV professional life	**.56**	**.62**	**.46**	-	103	102	102	102	183	182	183	183	150	149	145	150
05 TOL Intrinsic value	**-.22**	-.14	**-.19**	-.17	-	102	102	102	103	102	103	103	85	85	83	85
06 TOL Attainment value	.08	-.04	-.16	.04	.12	-	102	102	102	102	102	102	84	84	82	84
07 TOL UV study program	.10	.13	.12	.06	.16	.10	-	102	102	102	102	102	84	84	82	84
08 TOL UV professional life	.14	-.02	-.04	.03	**.43**	**.35**	.42	-	102	102	102	102	84	84	82	84
09 SDL Intrinsic value	-.02	**.16**	.01	.09	.02	.00	-.06	.02	-	182	183	183	150	149	145	150
10 SDL Attainment value	**.16**	.10	-.05	.01	-.05	.07	-.02	-.01	**.36**	-	182	182	149	148	144	149
11 SDL UV study program	.03	-.11	**-.39**	**-.15**	.07	.12	-.06	.08	**.22**	**.36**	-	183	150	149	145	150
12 SDL UV professional life	-.01	-.09	**-.15**	**-.20**	.03	-.06	-.08	-.07	**.16**	**.29**	**.27**	-	150	149	145	150
13 Interest in school math	.12	-.06	-.04	.13	.12	.12	.04	-.06	.09	-.06	.04	.02	-	149	145	150
14 Interest in university math	**.66**	**.35**	.12	**.49**	**-.21**	.03	.01	.05	.00	.07	.01	-.15	**.18**	-	145	149
15 Final school grade	-.07	.01	.06	-.08	-.06	.00	.09	.08	.10	-.13	**-.17**	.09	-.13	-.07	-	145
16 Gender	**-.20**	-.11	.08	-.12	.11	.05	-.04	.14	.06	-.06	-.05	-.07	.11	-.14	-.13	-

Note: MOL: mean of observations across lessons; TOL: Trend of observations across lessons; SDL: Standard deviation of observations within lessons; UV: utility value. Gender was dummy-coded (0 = male, 1 = female). The underlying sample size is indicated above the diagonal line. **Bold** correlations were significant at a $p < .05$ (two-tailed)

ematics correlated with one of these trends: a high interest in university mathematics at the beginning of the course was accompanied by an even more negative trend in intrinsic value ($r = -.21$). No other relations between task value component trends and individual characteristics were significant.

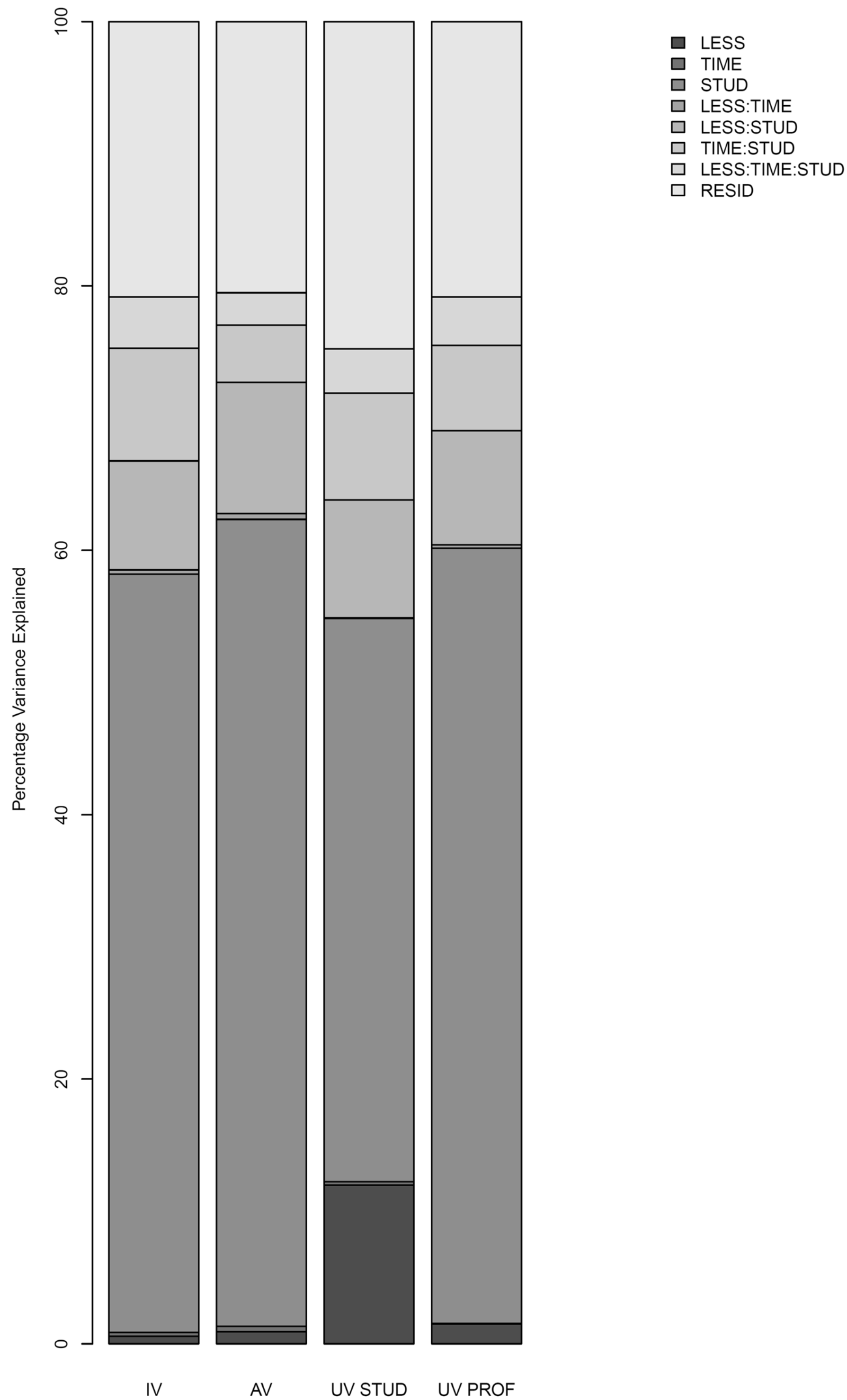

Fig. 4 Variance decomposition of components of task values by the time point in the lesson, time point of the lesson, student, and interaction between time points and student; IV: intrinsic value; AV: attainment value; UV STUD: utility value for the study program; UV PROF: utility value for professional life. TIME: time point in the lesson; LESS: time point of the lesson; STUD: student; RESID: residual

5.4 Task value component fluctuations within lessons and their relations to individual characteristics

The standard deviations of the observations within lessons indicated the extent to which the task value components fluctuated within lessons. All task value components hardly fluctuated between the time points in the lessons, as shown by the variance decomposition in Fig. 4. Utility value for the study program of students with a better final school grade fluctuated more within the lessons than that of students with a worse final school grade (r = -.17, a lower value of the final school grade means a higher achievement; Table 3). Additionally, t-tests indicated that pre-service mathematics teachers reported higher fluctuations in utility value for the study program than mathematics students (*Estimate* = 0.14, $SE = 0.08$, $p = .07$). No other relations between task value components fluctuation and individual characteristics were significant.

6 Discussion

6.1 Summary and implications

This study contributes to the literature by focusing on both individual and situational factors, the time and context-dependency (Pekrun & Marsh, 2022), of task value components in a university mathematics course. As some students symptomatically report low value beliefs in such courses, researchers and practitioners are developing interventions to foster these motivational beliefs (Eichler & Isaev, 2023; McGuffey et al., 2019; Rach & Schukajlow, 2023). Understanding how task value components relate to each other, which individual characteristics relate to the components, and how time-consistent these components are, hence configures a first step toward clarifying the mechanisms at work and, ultimately, developing and successfully implementing such interventions.

The study results lead to the following two main insights. First, the situation-specificity of task value components: many students did not differentiate between different contents when rating their value beliefs (see Fig. 4), meaning that, for many students, it did not matter much which mathematical concept was defined, which theorem was proven, or whether an application was presented. This phenomenon may occur because many first-semester students become overstrained with the task of comprehending the lectures (Umgelter & Geisler, 2024), which may lead them not to be able to perceive the content in a manner that enables them to evaluate their task values appropriately. This explanation is supported by the observation that students with a high interest (vs. low) in university mathematics showed a more negative trend in intrinsic value during the semester. This is also aligned with the findings of Fryer et al. (2025), who report a negative relation between prior domain interest and the slope of teaching course interest. Considering the context of the present study, we assume that interested students may be depressed by the high demands of the course because they feel that they cannot perceive the differences between contents and learn anything about university mathematics.

Second, characteristics of value components: intrinsic value was strongly related to interest in university mathematics and showed little time change. This result contradicts the results of Parrisius et al. (2022) and may be explained by the aforementioned overload that students experienced in these lectures. Another explanation for the low change in intrinsic value over time can be found in the observations provided by Asada et al. (2024): students may evaluate enjoyment based not on the action but on the outcome and consequences (see Fig. 1; Urhahne & Wijnia, 2023). In this case, intrinsic value is closely connected to both attainment and utility value. Moreover, attainment value changed only marginally during the semester or one lesson. This concurs with Benden and Lauermann's (2023) assumption that task importance for one's identity increases over an extended period, as students must incorporate the task into their identity (see also Eccles & Wigfield, 2024). In addition, the two facets of utility value showed different patterns according to situations and students.

The theoretical implications refer to the various situation-specificity of task value components. It may be valuable to not only measure task values as a joint scale but also differentiate between value components to gain more insights into the situation-specificity of value beliefs (see Benden & Lauermann, 2023; Gaspard et al., 2015; Gildehaus et al., 2024b). In addition, various results on moment-to-moment changes in the value components differ between the present study and that of Moeller et al. (2022), highlighting the impact of the learning setting.

Regarding methodological implications, we used three fluctuation measures and showed that time points can explain only a marginal variance in task value components. These results mean that approaches that repeatedly measure task values during learning processes, such as experience-sampling approaches (Moeller et al., 2022), are not always sensitive enough to produce valuable insights into motivational processes in university mathematics courses. Other item formulations, which may be more concrete or even more measurement points to detect quick changes in students' task values, may be needed.

Pertaining to practical implications, we hope that our evidence helps foster value beliefs in university mathematics courses. As pre-service mathematics teachers (vs. mathematics students) often reported lower value beliefs, this vulnerable student group requires more explicit attention. Prior intervention studies focused on fostering utility value (for professional life) (Eichler & Isaev, 2023; Rach & Schukajlow, 2023). However, in this study, utility for the study program fluctuated more between lessons than did utility value for professional life; this higher fluctuation means that interventions focusing on utility value for the study program may be more beneficial. Nevertheless, it is important to consider all components (e.g., attainment value with a longer-lasting intervention) in order to enable students to build their identities as "mathematics-persons" (see Gildehaus et al., 2023). Eccles and Wigfield (2024, p. 19) proposed ideas to foster attainment value by providing "students with information on the link between potential associated job characteristics with the students' goals and identities." (see also Büdenbender-Kuklinski et al., 2024). To make effective use of these opportunities, students need a certain level of reflection skills, which may be too demanding in a first-semester course due to the challenging transition (Montecino & Andrade-Molina, 2024).

This study also affords practical implications for lectures. Umgelter and Geisler (2024) observed that informal aspects of mathematical concepts (e.g., the motivation for a concept) are more often presented orally than in written form, which may hinder students from realizing that these informal aspects are also part of university mathematics. In the present study, many students did not seem to recognize that the lecturer visualized the mathematical information as he/she referred to a card game or used a more student-centered method of asking mathematical questions. We argue that lecturers should present the informal aspects of concepts and statements also in written form, so that students can realize that these informal aspects, which they probably know from school, belong to university mathematics. This may be particularly important for pre-service teachers who evaluate utility value for professional life according to school mathematics. Guo and Fryer (2025) confirmed that techniques that lecturers apply in their courses, such as asking students questions to activate them cognitively, can stimulate students' motivation in the moment.

6.2 Limitations and future research

This study had some limitations. The sample size for the time points decreased during the semester, mainly owing to course or study program dropouts (Geisler et al., 2023a). This implies that our results are valid for students who participated in the course throughout the semester. As some students reported only one value in the semester, we could not estimate the variance for these students; thus, we may have underestimated task value component fluctuations. Regarding individual characteristics, we focused on interest facets, gender, study program, and prior achievement. Further studies could address the interactions between value components and self-concept or prior knowledge.

Due to practical issues, we measured every task value component using only one item. As attainment value comprises identity-related and achievement-related facets, measuring both facets separately may provide more insight. In addition, one may consider a realistic period for attainment value, which is closely connected to students' identities, to change, and use such a realistic period in further studies.

It is possible that our item formulation, including the prompt, was not sensitive enough to measure fluctuations in value beliefs because it may be that students did not consider the content in the last couple of minutes, but rather the content of the whole lecture course, in responding to the questionnaire. Törmänen et al. (2025) suggested using other measurement forms, such as log data, when working on tasks or facial expressions amid lecture participation.

In addition, our findings do not provide any evidence on the situation-specificity of task values when the instruction form changes, for example, from lecture-oriented to student-oriented, such as in flipped classrooms (Van Alten et al., 2019). As we did not observe the lessons systematically, we could not identify situational variables (e.g., authentic examples) that impact students' task values. In future studies, the quality of a lecture's single lesson (Umgelter & Geisler, 2024) should be linked to fluctuations in students' task values.

6.3 Conclusion

This study contributes to two debates concerning mathematical learning processes at universities: about the characteristics of the different task value components and interventions in teacher education programs. The task value components in this study showed various patterns, such as fluctuations. In addition, they were shown to depend more on the student than on the actual situation. Many researchers agree that university mathematics is a must-have in teacher education programs (Wasserman et al., 2023). Thus, it is important to understand how to enhance pre-service teachers' value beliefs when dealing with university mathematics—in fact, we believe this to be a leading question for further research. The model of Urhahne and Wijnia (2023, Fig. 1) may help systematize existing interventions (e.g., Parrisius et al., 2020; Rosenzweig et al., 2022): the value components refer to different stages of the learning process, which can be addressed by different interventions separately.

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Declarations

Competing Interests The authors have no relevant financial or non-financial interests to disclose.

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