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Impact of a Mathematics Bridging Course on the Motivation and Learning Skills of University Students

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Abstract
The transition from secondary to tertiary education is an exciting and yet challenging event in the educational biography of students. During this transition, students often meet with unexpected challenges, which may cause them to drop out from their degree program. Many universities offer bridging courses or longer-term interventions to support their incoming students in this period. To examine the effect of a bridging course designed to reduce gaps in prior mathematical knowledge, promote social-emotional well-being, and foster learning skills, we implement a repeated-measures intervention study. We analyze the outcomes of the intervention, which features tutors with special training, autonomous choice of topic areas, peer learning, and materials for self-directed learning. We measure the development of motivational beliefs reflecting the will to learn (achievement goals, satisfaction of basic psychological needs, implicit theories, self-efficacy) and the skills to learn (reactions to errors, self-regulated learning) at the secondary-tertiary transition. These aspects are captured at multiple measurement points among students (N = 679) who participate in the bridging course (intervention group) and those who do not (control group). The intervention boosts motivational beliefs related to social embeddedness and learning skills in the short term. The observed decrease in autonomy, competence, and self-efficacy might be explained by higher standards that students use for their self-assessment in the new peer group. In the long term, all aspects of the will to learn, except for social relatedness, show stable to strongly negative developments in both groups. Among those students who do not participate in the bridging course, mostly strongly negative developments are observed. The results suggest that the peer tutoring strategy is highly effective and the need for longer-term interventions to uphold the positive short-term effects.

Keywords Achievement goals · Bridging course · Learning strategies · Mathematics · Repeated-measures design · Secondary-tertiary transition

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Introduction

The transition from secondary to tertiary education is an exciting, yet challenging period in the biography of students. They are aware that success or failure at this transition may well decide whether they will be able to reach the educational goals they have set for themselves. For instance, between 2015 and 2020, roughly one third of bachelor level students in Austria dropped out from their programs within the first two semesters (Statistics Austria, 2019, 2020, 2021, 2022). Heublein et al. (2017) have identified nine categories of motives of why students drop out from their chosen degree programs across all fields. The most important motives are *problems in performance*, *lack of study motivation*, and *vocational orientation* (e. g., the desire for practical activities). Code et al. (2016) have investigated the development of motivational indicators among first-year mathematics students and found that all of them decline within the first year at university. Liebendörfer (2018) has emphasized the important role of the institutional environment on the development of mathematics students' motivation.

The institutional environment at universities differs substantially from that of secondary schools. The ensuing challenges for mathematics students have been examined based on theories of person-environment fit, for example, by Geisler and Rolka (2021), who found that favorable student beliefs related to mathematics decrease significantly during the first eight weeks at university, fueling dropout intention. At universities, the student-teacher ratio is higher than at school, summative forms of assessment may be more prevalent (Yorke, 2003), and self-organization skills and time management skills play a greater role. Furthermore, mathematics at university requires students to work more independently than many are used to at school (e.g., Christie et al., 2013; O'Shea & Breen, 2021). This and the more scientific flavor of mathematics required at university may be unexpected for many students, trigger negative emotions, and cause students to perceive themselves as less able (Di Martino et al., 2022b). For students who have little or no previous experience with scientific mathematics, adapting suitable learning strategies for the transition to university may be a greater challenge (Rach & Heinze, 2016). At many universities, the successful completion of initial courses is necessary to continue further into the degree, with the consequence that incoming bachelor mathematics students experience high pressure and often engage in extrinsically motivated activities (Liebendörfer, 2018). Furthermore, they often attempt to adapt learning strategies geared to fulfilling passing requirements (Göller, 2020) such as aligning their time management to the requirements of mandatory courses and seeking help from other students to complete assignments. To sum up, the challenges at the transition from secondary to tertiary education are multi-layered (Heublein et al., 2017).

However, to facilitate the transition and to reduce dropout rates, universities can provide structured support to strengthen students' prerequisite competencies for their degrees of study. Such "bridging courses" are offered before or at the beginning of the first semester. In German-speaking countries, many support programs in mathematics have been developed (e. g., Austrian Mathematical Society, 2022; Heublein et al., 2017). Lankeit and Biehler (2018) reported that, in German universities, the self-perceived readiness for university studies increased considerably after participating in a mathematics bridging course. However, they also concluded that the students had a different perception of mathematics after the bridging course, supporting the assumption that there are qualitative differences in how mathematics is taught at universities and in secondary schools (Lankeit & Biehler, 2018).

Well aware that much research has been devoted to bridging courses, the scientific literature – to the best of our knowledge – lacks evidence-based studies evaluating the design of interventions at the secondary-tertiary transition (Gueudet, 2023; Pinto & Koichu, 2023) and, in particular, the impact of bridging courses on the development of learning skills and motivation. To make such a contribution, this work reports results from a questionnaire study on the bridging course offered by the Faculty of Mathematics of the University of Vienna, whose main focus lies on closing gaps in prior mathematical knowledge and on fostering the social embeddedness and learning skills of students starting bachelor programs in the fields of science, technology, engineering, and mathematics (STEM). We build our investigations upon previous findings of features and expectable outcomes of interventions that have been found to have potential for facilitating the transition from school to university. Regarding teaching methods, the assessment of the intervention in this work is based on observations of peer tutoring facilitating student motivation and student onboarding (Mean & Maciejewski, 2021). Moreover, we rely on the finding that mathematical tasks can guide students in getting acquainted with the nature of mathematics as taught and used at university (O'Shea & Breen, 2021). Finally, the central postulations of the *self-determination theory* (SDT; Deci & Ryan, 2000, 2008, 2015), i. e., that the perception of autonomy, competence, and social relatedness improves students' well-being, shape large parts of the design and the investigation of the intervention.

The constructs we investigated concern motivational beliefs and related aspects that are crucial for a positive attitude towards lifelong learning and studying at university in particular.

Theoretical Background

In this work, we investigate the impact of a bridging course on the development of social embeddedness and learning skills. We aim to contribute empirical findings on which features of support programs students can benefit from at the secondary-tertiary transition.

Intervention

In Austria, many universities offer bridging courses for incoming bachelor students in degree programs that require a substantial amount of mathematics (Austrian Mathematical Society, 2022). At the Faculty of Mathematics of the University of Vienna, a five-day bridging course is offered just before the start of the winter semester. The intended effect of the bridging course has been operationalized by three goals. Firstly, the intervention aims to reduce the gaps in prior mathematical knowledge of beginning students. This includes the consolidation of procedural and conceptual knowledge typically expected from beginning students by university teachers, rectification of common mathematical misconceptions, and creating awareness for discrepancies between the focus of the Austrian school leaving exam and the competencies needed at the beginning of study programs rich in mathematics. This bridging course does not anticipate new mathematical content of first-semester courses. Secondly, the intervention aims to foster social-emotional well-being and a confident attitude towards new challenges. The participants are introduced to their new environment at university, receive personal attention, meet peers, find study partners, and test their skills. Thirdly, the intervention aims to foster learning strategies and learning skills including awareness and application of internal resources such as persistence and handling of setbacks as well as external resources such as actively seeking support from others. The overarching goal of the bridging course is to support able and dedicated students to succeed in their study programs.

To achieve these goals, the bridging course has several features (F1-F6) which are expected to be conducive to the outcomes O1-O6. For an overview of the features and expected outcomes, see Table 1. In the bridging course, the participants receive mathematical inputs from peer tutors and engage in self-directed and collaborative learning (F1). At the beginning of each day's four-hour session, the tutors recall core concepts of the topic area chosen by their group, point out available learning materials, and make suggestions on where and how to get started. The participants then engage in problem solving activities in the topic area with assistance and encouragement from their tutors. They collaborate with their peers or work on their own, as they prefer. Based on the recommendation of Mean and Maciejewski (2021) to

Table 1 Overview of the features (F1-F6) of the bridging course and the expected outcomes (O1-O6)

Features	
F1	Tutors give mathematical inputs and provide assistance with self-directed and collaborative learning
F2	Participants choose each day which topic to work on
F3	Participants work on a topic in small groups with a tutor
F4	Tutors are pre-service mathematics teachers
F5	Use of well-established materials designed for self-directed learning based on school curricula
F6	Active onboarding of participants
Expected outcomes	
O1	Participants are eager to master mathematical concepts and to do well in their courses
O2	Participants gain confidence to take on academic hurdles
O3	Participants have an improved sense of well-being at university
O4	Participants apply coping, metacognitive, organizational, and peer learning strategies
O5	Participants consolidate their mathematical competencies and close gaps
O6	Participants are familiar with basic processes at university

enhance student motivation by including peer instructors into learning environments, we expect the pedagogical setup of the bridging course to impact the participants' determination and how they manage their learning. Specifically, we expect that this approach motivates students to master the concepts of the topic area and fosters their determination to do well in their courses (O1) and also that it bolsters their confidence to take on hurdles such as exams (O2). In this way, we expect the intervention to be able to counteract the decline in confidence and favorable mindset as observed by Code et al. (2016). Moreover, we anticipate that this approach fosters favorable coping, metacognitive, and organizational strategies in the participants (O4) and, finally, that it helps the participants consolidate their mathematical competencies (O5).

To accommodate individual needs, starting the second day of the bridging course, the participants choose themselves which mathematical topic area to focus on each day (F2). The five topic areas are (1) basic algebra & elementary functions; (2) trigonometry & vectors; (3) differentiation; (4) integration; and (5) stochastics & statistics. On the first day, all students work on basic algebra & elementary functions. This feature of the bridging course should foster the autonomy aspect of well-being in terms of the SDT by promoting a sense of autonomy (O3) and, again, help participants consolidate their mathematical knowledge and competencies (O5).

The participants work in small groups (F3) which should address the relatedness aspect of the SDT and thus increase their sense of well-being by establishing connections with peers (O3), foster peer learning strategies by making students aware of peers as a resource for support (O4), and help them close gaps in their mathematical knowledge (O5). The participants are grouped by study program on the first day of the bridging course so they can get to know their immediate peers.

The tutors of the bridging course are experienced peers who are, for the most part, pre-service teachers at an advanced stage of their training (F4). They have previously completed a special course where they are trained in classroom management, use of materials on the aforementioned topic areas, and sensitivity towards gender, diversity, and math anxiety. Based on the work of Mean and Maciejewski (2021), we expect that the participants of the bridging course benefit from the experience and the advice of their tutors and that they adapt their suggestions of strategies to organize their learning and cope with setbacks (O4). Moreover, we expect that the input and the guidance of the tutors on the mathematical topic areas support the participants in consolidating their mathematical knowledge (O5).

The tutors draw from a large range of well-established and quality-assured learning and practice materials designed for self-directed learning (F5). These materials are based on the curricula of Austrian upper secondary schools. Since the choice of mathematical tasks can have a substantial impact on getting acquainted with university mathematics (O'Shea & Breen, 2021), this feature should support the participants in consolidating their mathematical knowledge (O5).

At the end of each session, the participants are encouraged to also ask questions on organizational matters related to their degree programs and benefit from the tutors' experiences. The tutors offer tours of the infrastructure and its facilities (e.g., library, study areas). Since, according to Mean and Maciejewski (2021), such peer group activities are perceived as particularly helpful for course participants, we expect that these onboarding activities (F6) foster the participants' well-being (O3) and help them get acquainted with basic processes at university (O6).

The bridging course was affected by federal restrictions related to the COVID-19 pandemic. To participate in the bridging course, students were required to have tested negatively for, to be vaccinated against, or to have recovered from COVID-19.

Successful Transition and Lifelong Learning

By entering university, high school graduates make a conscious choice to invest in their education in the sense of lifelong learning. The European Commission (2001, p. 9) defines *lifelong learning* as "all learning activities undertaken throughout life, with the aim of improving knowledge, skills, and competence within a personal, civic, social, and/or employment-related perspective". The importance of promoting lifelong learning has been recognized and emphasized in many studies (e.g., Lüftenegger et al., 2012, 2016). For the promotion of lifelong learning, motivational dispositions for a positive attitude towards learning (*will to learn*) as well as resources and capabilities for self-regulated learning (*skills to learn*) are considered crucial (Lüftenegger et al., 2012). The questionnaire used in this study to investigate how a bridging course can impact these attitudes and skills has been designed based on these constructs. Table 2 provides an overview of the theoretical constructs related to the will to learn and the skills to learn that are presented in the following sections.

Will to Learn

Lüftenegger et al. (2012) speak of the will to learn as "persisting motivation and an appreciation for learning and education". To operationalize the notion of "will to learn", a variety of aspects of achievement motivation can be taken into account. In this work, we view the will to learn of beginning university students as expressed in (1) the pursuit of favorable goals, (2) well-being in terms of satisfaction of basic psychological needs in the university context, (3) beliefs related to the efficacy of learning, (4) self-efficacy, and (5) readiness to take on academic hurdles such as exams.

There are well-established theoretical constructs that correspond to these five aspects and which we have used to design the questionnaire for this study. *Achievement goal theory* explains the interplay of *goal orientations* and *achievement motivation* (e.g, Dweck, 1986; Elliot & Thrash, 2001; Nicholls, 1984). This theory stresses the importance of goal orientation over specific goals to anticipate different types of achievement motivation. Mastery goals, performance approach goals, and performance avoidance goals are widely considered the key manifestations of achievement goal orientations. *Mastery approach goals* refer to the aspiration and wish to master a subject, *performance approach goals* (e.g., "My goal at university is to perform better than the other students.") refer to the incentive of surpassing others, and *performance avoidance goals* (e.g., "My goal at university is to avoid doing worse than other students.") refer to the motive of fulfilling external expectations and of not being surpassed by others (Elliot & Thrash, 2001). Achievement

Table 2 Overview of constructs covered at three measurement points (MP1, MP2, MP3) categorized by the determinants of lifelong learning *will to learn* and *skills to learn*

Construct	Items	Sample item (MP2)	Reliability (McDonald's ω)		
			MP1	MP2	MP3
Will to learn					
Achievement goals (original scales: Elliot & Murayama, 2008)					
Mastery approach goals (to develop new skills and improve one's level of competence)	3	*My goal at university is to learn as much as possible.*	.74	.74	.77
Performance approach goals (to demonstrate competence and ability in comparison to others)	3	*My goal at university is to perform better than the other students.*	.89	.86	.89
Performance avoidance goals (to avoid failure and unfavorable judgments of one's ability by others)	3	*My goal at university is to avoid doing worse than other students.*	.93	.92	.92
Basic psychological needs (original scales: Holzer et al., 2021)					
Autonomy (to perceive oneself as being able to make independent decisions)	3	*In the first six weeks at university, I could study at my own pace.*	.82	.79	.74
Competence (to perceive oneself as capable)	3	*In the first six weeks at university, I have managed to do most of my tasks really well.*	.79	.79	.86
Social relatedness (to perceive oneself embedded in the social environment)	3	*There are people who I told when I had achieved something in the first six weeks at university.*	.77	.79	.82
Implicit theories (original scale: Spinath & Schöne, 2003) (convictions of one's ability to be a malleable or fixed trait)	3	*Everyone has a certain level of mathematical ability. This level can (not) be changed.*	.78	.85	.84
Self-efficacy (original scale: Schwarzer & Jerusalem, 2003) (to be convinced that one is able to achieve goals)	5	*In the first six weeks at university, I know that I could find a solution for any problem.*	.90	.85	.87
Skills to learn					
Reactions to errors (original scales: Dresel et al., 2013)					
Action adaptivity (to emerge stronger from errors)	3	*After a failure in maths class, I work even harder in this subject.*	.80	.79	.78
Affective-motivational adaptivity (to be upset and react helplessly in the face of errors)	3	*After a failure in maths class, I get frustrated.*	.83	.84	.84

Table 2 (continued)

Construct	Items	Sample item (MP2)	Reliability (McDonald's ω)		
			MP1	MP2	MP3
Self-regulated learning (original scales: Pintrich et al., 1991)					
Effort regulation (students' ability to control their effort and attention in the face of distractions)	4	*In the first six weeks at university, I often felt so lazy or bored when studying that I quit before I finished what I had planned to do.*	.64	.66	.72
Elaboration[a] (students' ability to build internal connections between items to be learnt)	3	*In the first six weeks at university, I pulled together information from different sources, such as lectures, readings, and discussions.*	.49	.64	.49
Help seeking (students' ability to identify someone to provide them with assistance)	3	*When I could not understand the material in the first six weeks at university, I asked other students for help.*	.67	.68	.71
Metacognitive self-regulation[a] (students' ability to plan, monitor, and regulate their learning processes)	3	*In the first six weeks at university, I tried to think topics through and to decide what I am supposed to learn from them rather than just reading through them when studying.*	.63	.38	.65
Organization (students' ability to select appropriate information and construct connections among the information to be learnt)	3	*In the first six weeks at university, I outlined the material to help me organize my thoughts.*	.70	.75	.69
Peer learning (students' ability to collaborate with peers)	3	*In the first six weeks at university, I tried to work with other students to complete the course assignments.*	.64	.76	.81

[a]Due to insufficient reliability (ω < .6) this construct was analyzed using the item that seems to best represent the core of the construct

goals have been found to predict intrinsic motivation (positively: mastery approach goals; negatively: performance avoidance goals) and exam performance (positively: performance approach goals; negatively: performance avoidance goals) (Elliot & Thrash, 2001).

Well-being is a many-facetted psychological construct that has been identified as a key factor of successful learning. *Self-determination theory* (Deci & Ryan, 2000, 2008, 2015) proposes that the basic psychological needs *autonomy*, *competence*, and *social relatedness* foster intrinsic motivation and that the satisfaction of these needs is indicative of well-being. Moreover, studies have shown that the satisfaction of these needs is positively correlated with persistence in learning (e.g., Holzer et al., 2021; Lavigne et al., 2007), and negatively correlated with procrastination (e.g., Holzer et al., 2021).

Students' beliefs related to the efficacy of learning regulate their learning behavior and, in particular, their behavior in the event of setbacks. Known as *implicit theories*, two main sets of beliefs related to efficacy of learning have been identified: *incremental theories*, where intelligence is considered a malleable quality, and *entity theories*, where intelligence is taken as a given (Dweck et al., 1995). Learners holding entity theories are more likely to show helpless reactions in the event of setbacks. By contrast, learners with incremental theories relate setbacks to lack of effort or a poor choice of learning strategies. Therefore, they react to setbacks by trying harder or by adapting their strategies (Dweck et al., 1995). In this work, we consider the manifestations of implicit theories as highly relevant for a persistent will to learn at the secondary-tertiary transition.

Self-efficacy is a domain-specific psychological construct related to the perception of one's capabilities to achieve certain goals (Zimmerman, 1995) and is intimately tied to the will to learn (Lüftenegger et al., 2012). Self-efficacy correlates highly with persistence when performing tasks and with developing specific skills (e.g., Schunk, 1984). Van Dinther et al. (2011) summarize that "self-efficacy influences motivation and cognition by means of affecting students' task interest, task persistence, the goals they set, the choices they make and their use of cognitive, meta-cognitive and self-regulatory strategies". Self-efficacy has also been found to correlate with grades in mathematics courses (Hailikari et al., 2008). It can thus be expected that students at the secondary-tertiary transition with high self-efficacy in their domain are more likely to succeed in their degree programs than those without.

Skills to Learn

For learners to be successful, not only the appreciation for learning, i. e., the will to learn, is crucial, but also the ability to adopt suitable learning behaviors, i. e., the skills to learn. We use the theory of self-regulated learning to operationalize the skills to learn. According to Zimmerman (2008), self-regulation is "significantly correlated with measures of course performance". For this reason, self-regulation is an important determinant of a successful transition. McKeachie et al. (1986) distinguish between *cognitive strategies*, *metacognitive strategies*, and *resource management strategies* employed by learners. Cognitive strategies include *organization strategies* and *elaboration strategies*. Metacognitive strategies comprise strategies of *planning*, *monitoring*, and *regulating*. From among the resource management strategies proposed by McKeachie et al. (1986), we consider *support of others* and *effort management* in this study.

As students need to adapt to a new environment and engage with mathematics of a kind and in a way that differs from school, the way in which they are dealing with setbacks likely affects their success at the beginning of their degree programs. A framework for this is provided by Dresel et al. (2013) who found out that *affective-motivational reactions on errors* (e.g., negative emotions, helpless coping style) lead to reduced effort, avoidance of challenges, and, eventually, to lower achievement on part of the students. In contrast, *action-adaptive reactions on errors* (e.g., adjusting learning strategies) lead to increased effort and a positive attitude towards future learning.

Research Aims and Hypotheses

In this study, we consider a transition successful if the development of the will to learn and the skills to learn is stable or positive. The transition period is defined as the time between the students' arrival at university, i. e., the beginning of the bridging course or the first week of the semester, and their first exams. We assume that students generally set high expectations for themselves when entering university, so we also consider stable developments as indicative of a successful transition. We do not examine in this study the effect of the intervention on the consolidation of mathematical knowledge (O5) and on the participants' familiarity with basic processes at university (O6).

In the intervention group, we expect the psychological constructs described above to develop positively in the short term and to remain stable in the intermediate term. In the control group, we anticipate a negative development of these constructs in the intermediate term since, according to Liebendörfer (2018), the demands of the first semester tend to foster extrinsic motivation and undermine intrinsic motivation.

Regarding the will to learn, we hypothesize that the intervention leads to the outcomes O1, O2, and O3 presented in "Intervention". For an overview of our hypotheses, see Appendix "Hypotheses". Concerning the students' eagerness to master mathematical concepts and to do well in their courses (O1), we hypothesize that the intervention leads to a favorable short-term development (H1a-c) of achievement goals. Anticipating a gain of participants' confidence to take on academic hurdles (O2), we hypothesize that implicit theories (H3a) and self-efficacy (H5a) develop positively in the short term. The expected improvement in the participants' sense of well-being at university leads us to hypothesize that the satisfaction of basic psychological needs increases (H2a-c).

Regarding the skills to learn, we expect that, as a result of the intervention, participants apply coping, metacognitive, organizational, and peer learning strategies (O4). Specifically, we hypothesize that reactions to errors (H4a-b), metacognitive strategies (H6b), organizational strategies (H6c) as well as help seeking (H6a) and peer learning strategies (H6d) develop positively in the short term. Exploratively, we have included several items in the questionnaire that are related to effort regulation and elaboration, which the intervention might foster.

Furthermore, we expect the development of achievement goals (H1d-f), basic psychological needs (H2d-f), implicit theories (H3b), reactions to errors (H4c-d), self-efficacy (H5b), and self-regulated learning (H6e-h) to show a stable or positive development in the period between arrival at university and the first exams.

Regarding the group of students who did not participate in the bridging course, we hypothesize a decrease of achievement goals (H1g-i), basic psychological needs (H2g-i), implicit theories (H3c), reactions to errors (H4e-f), self-efficacy (H5c), and self-regulated learning (H6i-l).

Regarding comparisons between first-semester students who participated in the bridging course and those who did not, we expect the development of achievement goals (H1j-l), basic psychological needs (H2j-l), implicit theories (H3d), reactions to errors (H4g-h), self-efficacy (H5d), and self-regulated learning (H6m-p) between arrival at university and the first exams to be statistically significantly more favorable among the participants of the bridging course than among the other students.

A pilot study was set up to examine the suitability and quality of the constructs used; the main study was carried out with several amendments to test these hypotheses. The changes in the main study concern the composition of the intervention group, a replacement of the measures of basic psychological needs, a shift from general measures to context-related measures, as well as the inclusion of additional measures.

Present Research

The purpose of this work is to determine the effect of an intervention at the secondary-tertiary transition in STEM fields that is designed to reduce gaps in prior mathematical knowledge and to foster confidence, social-emotional well-being, and learning strategies. The intervention examined in this work is the mathematics bridging course offered by the Faculty of Mathematics of the University of Vienna. It is hypothesized that participation in the bridging course has positive short-term and stabilizing intermediate-term effects. We measured the constructs underlying our hypotheses in a longitudinal study using a quantitative approach. We collected longitudinal data from incoming students at the beginning and the end of the mathematics bridging course in September 2019 and in the course of the winter semester 2019/20 as a pilot (see summary in "Pilot Study"). The main study was carried out in September 2021 and in the winter semester 2021/22. The data collection and analysis allow for comparisons in the development of students who participated in the bridging course (intervention group) and those who did not (control group).

Methods

Study Design

We set up a case-control study with repeated-measures design that focuses on the development of students' will to learn and skills to learn. The intervention group is made up of students starting a degree program at the Faculty of Computer Science or the Faculty of Mathematics of the University of Vienna. These were the two faculties whose degree programs were best represented by the participants in the bridging course 2021. The participants were about to enter a degree program in mathematics or in a field related to mathematics (Bachelor Astronomy; Bachelor Mathematics – Teacher Training Program; Bachelor Mathematics; Bachelor Meteorology; Bachelor Physics – Teacher Training Program; Bachelor Physics) in the winter semester 2021/22. We expect that the mathematics bridging course has a positive effect on how the participants transition from secondary to tertiary education. Thus, the intervention group is composed of students who participated in the bridging course and the control group is made up of students who did not participate.

A questionnaire survey was conducted in the intervention group at the beginning of the bridging course (measurement point 1 = MP1), one week later at the end of the bridging course (MP2), and – depending on the degree program, after another two to three months – shortly before the first exam of the first semester (MP3) to measure the hypothesized developments in the short term, i. e., between MP1 and MP2, and in the intermediate term, i. e., between MP1 and MP3 in the intervention group and between MP2 and MP3 in the control group. Since the bridging course was offered in three sections, participants received the first and the second questionnaire at different times (see Fig. 1) depending on the section they had registered for (Section A: afternoon sessions in week 1, B: morning sessions in week 2, C: afternoon sessions in week 2). In the control group, the students were surveyed at two measurement points, namely at the beginning of the first semester (MP2) and shortly before the first exam of the first semester (MP3). To increase the willingness to participate in the study, restaurant vouchers were raffled among students who participated at all measurement points.

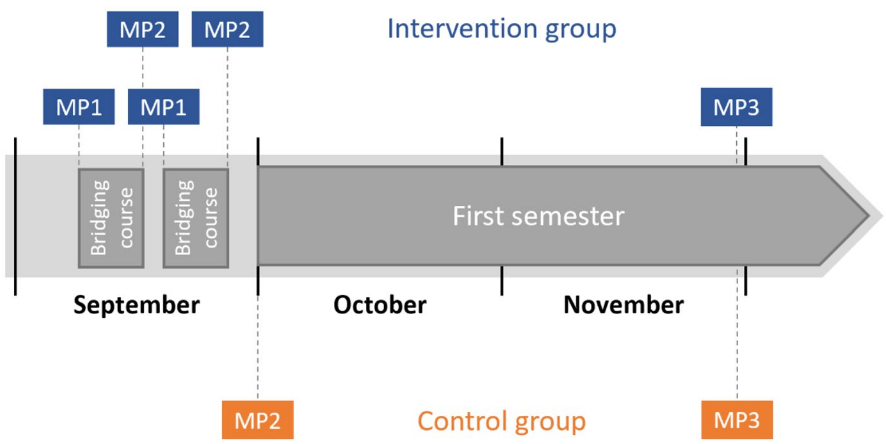

Fig. 1 Timeline of measurement points (MP) during the bridging course and the first semester in the intervention group and in the control group

Pilot Study

To trial the measurement instrument, a pilot study with 514 students entering STEM fields was carried out. The original instrument was composed mostly of items related to the will to learn (achievement goals, basic needs, implicit theories). Regarding the skills to learn, reactions to errors and the use of peer learning strategies were investigated. While the measures of achievement goals, implicit theories, and reactions to errors delivered reliable data, the scales of basic psychological needs did not fulfill minimum standards for reliability. The pilot study informed the selection of suitable measures for the main study (see "Measures").

The results of the pilot study show favorable development of achievement goals and implicit theories in the course of the intervention. The participants applied peer learning strategies much more at the end of the bridging course than at the beginning. In the intermediate term (MP3), perceived competence and affective-motivational reactions to errors developed negatively while most of the other constructs did not deviate statistically significantly from the initial level. Overall, the results of the bridging course indicate that during the intervention, aspects of the will to learn develop slightly positively or remain stable; in the intermediate term, they remain stable or develop slightly negatively. The same pattern emerged regarding the skills to learn in how students react to errors. However, peer learning strategies appear to be boosted during the intervention, which suggests that it might be worthwhile to consider also other learning strategies in the main study. For details on the results of the pilot study, see Appendix "Results of the pilot study".

Comparing the intermediate-term developments, the intervention shows a more favorable development than the control group. A closer examination of selection effects was implemented in the main study.

Measures

For measuring the constructs outlined in "Successful Transition and Lifelong Learning", we used scales from well-established questionnaires with a 6-point Likert scale (1 = "strongly disagree", 6 = "strongly agree"). We used the German translation of three scales of the *Achievement Goals Questionnaire-Revised* (Elliot & Murayama, 2008) to capture the achievement goals of incoming students: *mastery approach goals*, *performance approach goals*, and *performance avoidance goals*. We adhered to the established trichotomous model of achievement goal theory and omitted the subscale *mastery avoidance goals* since there is not yet substantial scientific support for inclusion of this aspect for this age group (Lee & Bong, 2016; Lüftenegger et al., 2019; Strunk et al., 2020).

To capture implicit theories of incoming students, we included three items of the *SE-SÜBELLKO-ST* scales (Spinath & Schöne, 2003) on the malleability of mathematics ability.

Adaptivity of reactions to errors in mathematics was measured using two short versions of Dresel et al.'s (2013) questionnaire on *affective-motivational adaptivity* and *action adaptivity of reactions to errors*. The wording of the items was adapted slightly to better fit the specific context of our study.

Scales of Holzer et al. (2021) consisting of adapted items from the *Work-related Basic Need Satisfaction Scale* (W-BNS; Van den Broeck et al., 2010) and the EPOCH Measure (Kern et al., 2016) were used to measure the satisfaction of *autonomy*, *competence*, and *social relatedness*. Additionally, items to measure *self-efficacy* of scales for general self-efficacy (Schwarzer & Jerusalem, 2003) and items to measure *self-regulated learning* from the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich et al., 1991) were included as context-specific versions in the questionnaire. Items from six subscales of the MSLQ were included in the questionnaire: *effort regulation*, *elaboration*, *help seeking*, *metacognitive self-regulation*, *organization*, and *peer learning*.

Sample

293 incoming students who were about to begin their studies for one of the aforementioned degrees participated in the questionnaire study at at least one measurement point, making up the intervention group. In the control group, 386 incoming students took part in the study at at least one measurement point.

672 of the 679 participants entered a study program at the University of Vienna. Most of the participants were in their first semester of their studies toward the degrees Bachelor Mathematics Teacher Training (25%), Bachelor Physics (24%), Bachelor Mathematics (21%), and Bachelor Astronomy (14%); the number of the participants starting their university career in the field of mathematics (N = 304) and in the field of physics (N = 304) is equal, each accounting for 45 % of the overall sample. Further details on the composition of the sample are provided in Appendix "Participants per measurement point".

Statistical Analysis

We measured the internal consistency of the scales using McDonald's omega and interpreted the measures as highly reliable for $\omega > .8$ and as sufficiently reliable for $\omega > .6$. To increase the statistical power of the data, missing data in the outcome variables were imputed using multiple imputation with five iterations (Lüdtke et al., 2007). The socio-demographic variables and the outcome variables were used as predictors for the imputed data. Imputation was carried out following the procedure of Rubin (1987). Missing data ranged between 0.3% and 3.0% for all items at each measurement point. For further details on the imputation procedure and imputation results see Appendix "Imputation".

To determine effect sizes, the Pearson correlation coefficient was used and interpreted as small for $r = .1$, medium for $r = .3$, and large for $r = .5$ (Cohen, 1988).

Considering the fact that neither participation in the bridging course nor in this study is mandatory for beginning students, a selection bias might appear in the intervention group (see also Di Martino et al., 2022a). Therefore, socio-demographic aspects and aspects related to the participants' educational biographies were included as control variables. We assumed that these control variables would most likely reveal such a bias. To test for a potential selection bias, the outcome variables as well as the control variables were examined for initial differences between the intervention group and the control group. Statistically significant differences were discovered in some variables, but, since they all have small effect sizes and do not all speak in favor of the same group, we considered the groups to be comparable at arrival at university. Details are provided in Appendix "Checks for selection effects". To study a potential bias due to the loss of those participants with specific characteristics at the last measurement point, the outcome variables and the control variables were examined for initial differences between those who participated at the last measurement point and those who did not. Results suggest that students who have better grades in the mathematics school-leaving exam and better psychological well-being upon arrival at university are more likely to participate at MP3 and, supposedly, to remain in their degree program. Details are provided in Appendix "Checks for selection effects". Since we did not detect further major differences between the intervention group and the control group upon arrival at university, we examined the development of the constructs using *t*-tests and analyses of variance (repeated-measures ANOVA).

For the intervention group, we examined the development of the outcome variables across the three measurement points by repeated-measures ANOVA. We used the results of the ANOVA to see whether the manifestation of constructs changes statistically significantly over time. To investigate when these changes arise, we considered within-subject contrasts between MP1 and MP2 and between MP1 and MP3. In the control group, we used paired-samples *t*-tests to examine developments.

Results

The results on the developments in the intervention group are presented in Table 3. The corresponding results for the control group are presented in Table 4. The overall intermediate-term developments across both groups and the interactions between the developments of the two groups are presented in Table 5.

Achievement Goals We measured achievement goals to examine the eagerness of participants to master mathematical concepts and to perform well (O1), which the tutoring strategy (F1) should foster. In the intervention group, mastery approach goals underwent statistically significant changes (see p-value for within-subject effects in Table 3). As can be seen in Fig. 2, contrasts confirm a statistically significant increase (medium effect size; see p-value and r-value for the short-term development in Table 3) in mastery approach goals in the short term, as hypothesized (H1a). A statistically significant decrease (large effect size; see p-value and r-value for the intermediate-term development in Table 3) in the intermediate term was observed in the intervention group, where a stable development had been hypothesized (H1d). In the control group, no statistically significant changes of mastery approach goals were observed (see p-value in Table 4), though a decrease had been hypothesized (H1g). A comparison of the developments in the intervention and control groups shows that, in contrast to our hypothesis (H1j), the development of mastery approach goals in the intervention group is statistically significantly worse than in the control group. Even though mastery approach goals were bolstered

Table 3 Developments in the intervention group

Construct	MP1	MP2	MP3	Within-subject effects				Short-term development				Intermediate-term development			
	M (SD)	M (SD)	M (SD)	F	df	df_R	p	F	df_R	p	r	F	df_R	p	r
Achievement goals															
Mastery approach	5.52 (.58)	5.67 (.44)	5.13 (.83)	18.716	1.498[a]	61.430[a]	<.001	6.703	41	.013	**.38**	13.748	41	.001	**.50**
Performance approach	3.55 (1.28)	3.68 (1.19)	3.36 (1.19)	2.193	1.894[b]	77.673[b]	.121	.926	41	.342	.15	1.539	41	.222	.19
Performance avoidance	3.88 (1.26)	4.04 (.99)	3.96 (1.25)	.440	1.839[b]	75.387[b]	.629	1.300	41	.261	.18	.206	41	.653	.07
Basic psychological needs															
Autonomy	5.38 (.97)	4.41 (.91)	3.29 (1.18)	47.954	2.000	82.000	<.001	20.195	41	<.001	**.57**	106.279	41	<.001	**.85**
Competence	4.98 (.78)	4.62 (.77)	3.87 (1.25)	16.906	1.839[b]	75.410[b]	<.001	5.089	41	.029	**.33**	25.431	41	<.001	**.62**
Social relatedness	4.06 (1.30)	5.06 (.96)	4.63 (1.25)	13.729	1.867[b]	76.530[b]	<.001	24.957	41	<.001	**.61**	7.267	41	.010	**.39**
Implicit theories	5.16 (.67)	5.22 (.68)	4.95 (.88)	3.279	1.613[b]	66.123[b]	.054	.626	41	.433	.12	2.615	41	.114	.24
Reactions to errors															
Action adaptivity	4.90 (.87)	5.17 (.68)	4.85 (.95)	4.506	1.831[b]	75.080[b]	.017	8.786	41	.005	**.42**	.136	41	.714	.05
Affective-motivational adaptivity	3.83 (1.28)	3.84 (1.40)	4.01 (1.35)	.725	2.000	82.000	.488	.004	41	.952	<.01	.949	41	.336	.15
Self-efficacy	4.72 (.94)	4.36 (.90)	3.24 (1.27)	35.226	1.882[b]	77.152[b]	<.001	5.748	41	.021	**.35**	52.341	41	<.001	**.75**
Self-regulated learning															
Effort regulation	4.61 (.89)	4.93 (.66)	4.09 (1.14)	12.535	1.934[b]	79.292[b]	<.001	4.690	41	.036	**.32**	7.607	41	.009	**.39**
Elaboration	4.30 (1.52)	5.10 (1.01)	4.60 (1.31)	6.432	1.723[b]	70.660[b]	.004	17.032	41	<.001	**.54**	1.208	41	.278	.17
Help seeking	3.10 (1.37)	4.30 (.97)	3.02 (1.18)	17.038	1.685[b]	69.071[b]	<.001	27.230	41	<.001	**.63**	.064	41	.802	.04
Metacognitive self-regulation	4.49 (1.48)	4.79 (.94)	4.20 (1.42)	3.149	2.000	80.000	.048	1.771	40	.191	.20	1.493	40	.229	.19
Organization	4.04 (1.17)	4.53 (.79)	3.28 (1.10)	32.191	2.000	82.000	<.001	10.924	41	.002	**.46**	19.942	41	<.001	**.57**
Peer learning	3.40 (1.14)	4.46 (.96)	3.23 (1.29)	17.420	1.957[b]	80.227[b]	<.001	22.691	41	<.001	**.60**	.430	41	.516	.10

Figures in boldface reflect statistical significance at the .05 level

M mean value, *SD* standard deviation, *F* ANOVA test statistics, *df* degrees of freedom, df_R df of residuals, *p* significance, *r* Pearson correlation coefficient

[a]Greenhouse-Geisser correction

[b]Huynh-Feldt correction

Table 4 Developments in the control group

Construct	MP2	MP3	Change			
	M (SD)	M (SD)	*t*	df	p	r
Achievement goals						
Mastery approach	5.13 (.95)	5.05 (.74)	-.844	91	.401	.09
Performance approach	3.27 (1.23)	3.08 (1.20)	-1.835	91	.070	.19
Performance avoidance	3.68 (1.39)	3.42 (1.22)	-2.433	91	.017	**.25**
Basic psychological needs						
Autonomy	5.43 (.65)	3.92 (1.20)	-11.452	91	<.001	**.77**
Competence	5.14 (.89)	3.82 (1.09)	-11.277	91	<.001	**.76**
Social relatedness	4.13 (1.34)	4.39 (1.41)	1.773	91	.080	.18
Implicit theories	4.96 (.81)	5.01 (.94)	.558	91	.578	.06
Reactions to errors						
Action adaptivity	4.91 (.91)	4.72 (.85)	-2.196	91	.031	**.22**
Affective-motivational adaptivity	3.82 (1.21)	3.93 (1.20)	1.125	91	.264	.12
Self-efficacy	4.81 (.90)	3.34 (1.06)	-12.286	91	<.001	**.79**
Self-regulated learning						
Effort regulation	4.58 (.98)	3.88 (.93)	-5.669	91	<.001	**.51**
Elaboration	4.20 (1.58)	4.07 (1.46)	-.750	91	.455	.08
Help seeking	3.32 (1.08)	2.87 (1.09)	-3.348	91	.001	**.33**
Metacognitive self-regulation	4.51 (1.37)	4.07 (1.29)	-3.000	91	.003	**.30**
Organization	4.03 (1.27)	3.32 (1.09)	-5.684	91	<.001	**.51**
Peer learning	3.54 (1.35)	2.97 (1.36)	-3.441	91	.001	**.34**

Figures in boldface reflect statistical significance at the .05 level

M mean value, *SD* standard deviation, *t* *t*-test statistics, *df* degrees of freedom, *p* significance, *r* Pearson correlation coefficient

significantly by the bridging course, high mastery goal orientation was not retained in the intermediate term.

Performance approach goals (H1b, H1e; see Fig. 2) and performance avoidance goals (H1c, H1f; see Fig. 2) did not change statistically significantly in the intervention group, quite as hypothesized. The intervention, which featured informal mathematical self-checks, did not impact performance goals noticeably. In the control group, no development of performance approach goals (H1h) was observed; however, performance avoidance goals (H1i) decreased statistically significantly (medium effect size).

Basic Psychological Needs Basic psychological needs were measured to study the well-being of students (O3), which should be fostered by autonomous choice of topic areas (F2), facility in the use of well-established materials designed for self-directed learning (F5), and social relatedness through the work in small groups (F3) and onboarding activities (F6). Perceived autonomy did not increase as hypothesized (H2a) but declined in the course of the intervention (large effect

Table 5 Intermediate-term developments across all participants (MP) and interaction effects between intermediate-term developments and participation in the bridging course (MP * GROUP)

Construct	PRE	POST	MP				MP * GROUP			
	M (SD)	M (SD)	F	df_R	p	r	F	df_R	p	r
Achievement goals										
Mastery approach	5.25 (.87)	5.08 (.76)	9.149	133	.003	**.25**	3.971	133	.048	**.17**
Performance approach	3.35 (1.25)	3.16 (1.20)	4.326	133	.039	**.18**	.002	133	.963	<.01
Performance avoidance	3.73 (1.35)	3.58 (1.25)	.632	133	.428	.07	3.010	133	.085	.15
Basic psychological needs										
Autonomy	5.41 (.76)	3.71 (1.23)	236.018	133	<.001	**.80**	6.781	133	.010	**.22**
Competence	5.09 (.85)	3.82 (1.15)	118.286	133	<.001	**.69**	.552	133	.459	.06
Social relatedness	4.12 (1.32)	4.47 (1.36)	10.202	133	.002	**.27**	1.389	133	.241	.10
Implicit theories	5.03 (.77)	4.99 (.91)	1.349	133	.248	.10	3.177	133	.077	.15
Reactions to errors										
Action adaptivity	4.91 (.89)	4.76 (.88)	2.845	133	.094	.14	.599	133	.440	.07
Affective-motivational adaptivity	3.82 (1.23)	3.96 (1.24)	2.225	133	.138	.13	.084	133	.772	.03
Self-efficacy	4.78 (.91)	3.30 (1.12)	178.594	133	<.001	**.76**	.023	133	.880	.01
Self-regulated learning										
Effort regulation	4.59 (.95)	3.94 (1.00)	31.736	133	<.001	**.44**	.497	133	.482	.06
Elaboration	4.23 (1.55)	4.23 (1.42)	.198	133	.657	.04	1.630	133	.204	.11
Help seeking	3.25 (1.17)	2.93 (1.12)	3.417	133	.067	.16	1.905	133	.170	.12
Metacognitive self-regulation	4.50 (1.39)	4.09 (1.32)	8.292	133	.005	**.24**	.183	133	.669	.04
Organization	4.04 (1.23)	3.30 (1.09)	48.333	133	<.001	**.52**	.158	133	.692	.03
Peer learning	3.50 (1.28)	3.06 (1.34)	5.752	133	.018	**.20**	2.157	133	.144	.13

Figures in boldface reflect statistical significance at the .05 level

M mean value, *SD* standard deviation, *F* ANOVA test statistics, df_R degrees of freedom of residuals, *p* significance, *r* Pearson correlation coefficient size; see Fig. 2). Moreover, a decrease in self-perceived competence was observed in the intervention group (medium effect size; see Fig. 2) at the end of the bridging course, other than hypothesized (H2b). In the intermediate term, the level of autonomy (H2d; large effect size) and of competence (H2e; large effect size) continued to decrease. In the control group, decreases in autonomy (H2g; large effect size) and competence (H2h; large effect size) of a similar extent could be observed. By contrast, the development of autonomy and competence was significantly more favorable in the pilot study. In this regard, we will discuss the potential impact of the COVID-19 pandemic (see "Discussion").

Groupwise comparisons show that autonomy decreased statistically significantly more in the intervention group than in the control group (H2j). The development of competence did not differ statistically significantly between the groups (H2k).

Perceived social relatedness (see Fig. 2) showed a statistically significant increase among participants of the bridging course. The increase was large in the short term (H2c) and of medium effect size in the intermediate term (H2f). In the control group, no statistically significant change in social relatedness was observed (H2i). The developments did not differ significantly between the two groups (H2l).

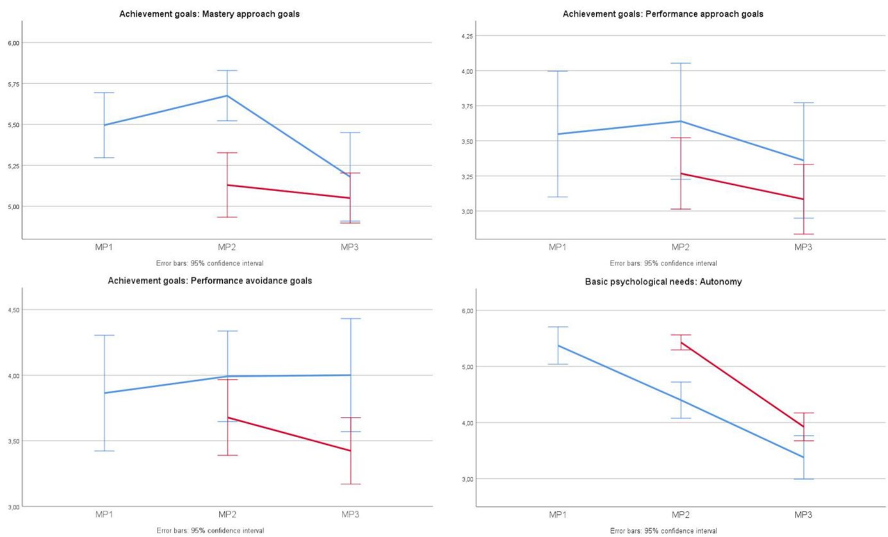

Fig. 2 Development across the measurement points (MP) of aspects of the will to learn in the intervention group (blue) and in the control group (red)

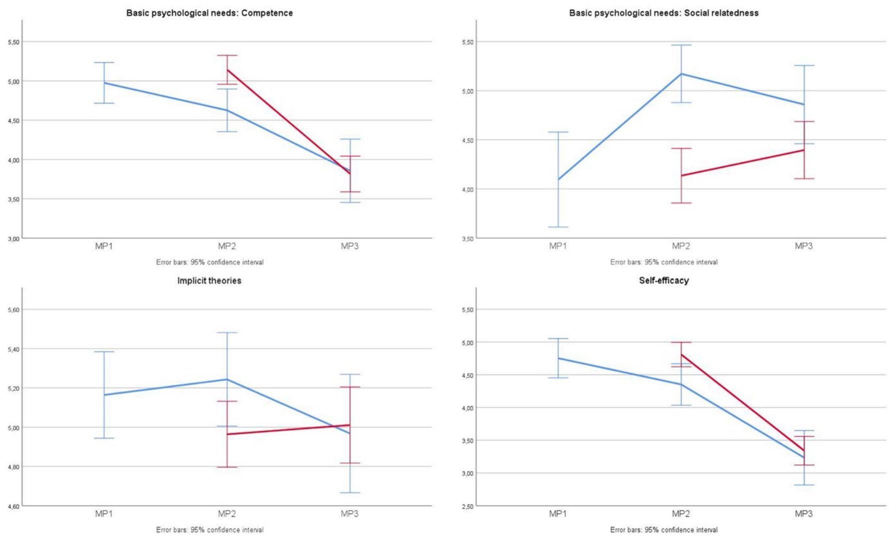

Fig. 2 (continued)

Implicit Theories Implicit theories were measured to assess in broad terms how confident students feel that their effort can increase their mathematics ability (O2), which should be fostered by the assistance and encouragement of the tutors (F1). No statistically significant short-term (H3a) or intermediate-term (H3b, H3c) changes in implicit theories were observed in either group. The comparison of developments (H3d) between the two groups did not reveal statistically significant differences either (see Fig. 2).

Self-efficacy Self-efficacy (see Fig. 2) was measured to obtain more specific information on how confident students are about learning mathematics at university level (O2) than that gleaned from implicit theories. We had hypothesized that self-efficacy increases in the short term (H5a) and remains stable in the intermediate term (H5b). However, we discovered a statistically significant decrease in the intervention group of medium short-term and large intermediate-term effect size. In the control group, the hypothesized intermediate-term decrease (H5c) was observed to be of large effect size. The developments in the groups do not differ statistically significantly from one another (H5d).

Reactions to Errors The reactions to errors of students were measured to gain insight into their use of coping strategies (O4), which we expected to increase on account of the assistance provided by the tutors (F1). As hypothesized, action-adaptive reactions to errors (see Fig. 3) of the participants developed positively with a medium to large effect size in the short term (H4a). In the intermediate term (H4c), action-adaptive reactions to errors returned to the initial level. Also as hypothesized, by comparison, the control group exhibited a negative development (H4e) of small to medium effect size. The intermediate-term developments do not differ statistically significantly between the two groups (H4g). Affective-motivational reactions to errors (see Fig. 3) remained stable across all measurement points in both groups (H4b, H4d, H4f, H4h).

Self-regulation We expected that the participants would benefit from the tutoring strategy (F1), from working in small groups (F3), and from the empathy of their tutors (F4), leading to the adoption of favorable strategies (O4). In the intervention group, with the exception of metacognitive self-regulation (H6b), all aspects of self-regulation (see Fig. 3) included in this study increased statistically significantly in the short term (H7a, H7c-d) with medium to large effect sizes. As for intermediate-term developments, no statistically significant changes were observed in elaboration, help seeking (H6e), metacognitive self-regulation (H6f), and peer learning (H6h), while effort regulation and organization (H6g) decreased with large effect size. In the control group, the changes in effort regulation, elaboration and organization (H6k) are comparable with those in the intervention group. However, different from the stable developments seen in the intervention group, statistically significant decreases in help seeking (H6i), metacognitive self-regulation (H6j), and peer learning (H6l) strategies of medium effect size were observed in the control group. A general decrease was observed with regard to effort regulation, metacognitive self-regulation, organization, and peer learning (all with medium to large effect sizes). The intermediate-term developments did not differ statistically significantly between intervention and control group (H6m-p).

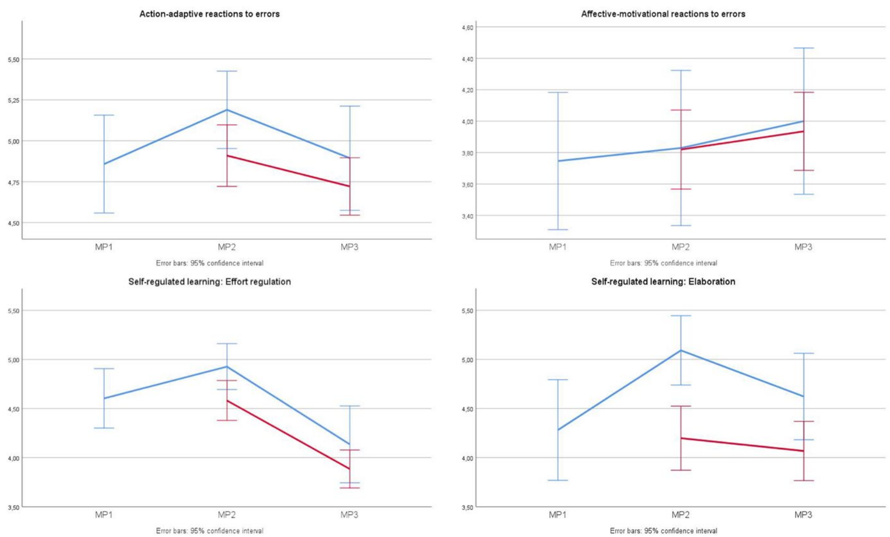

Fig. 3 Development across the measurement points (MP) of skills to learn in the intervention group (blue) and in the control group (red)

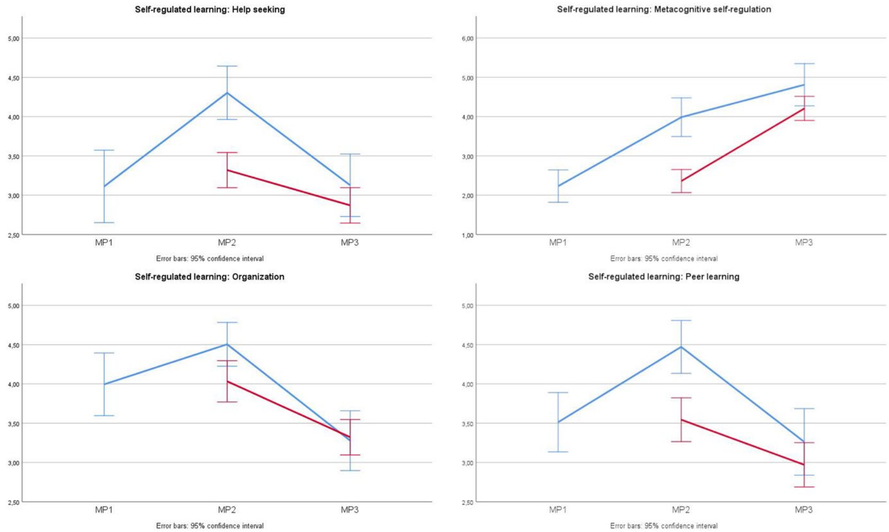

Fig. 3 (continued)

Summary

Short-term Developments We observed an increase in mastery orientation and a stable development of performance orientation from the beginning of the bridging course until the end. The aspects of basic psychological needs measured in our study develop differently. While the sense of social relatedness increased substantially, autonomy and competence decreased unexpectedly. In the pilot study, the development of autonomy and of competence was stable.

A strongly positive development of self-regulated learning strategies was observed in the participants of the bridging course, suggesting that the design of the bridging course bolsters the participants' skills to learn. A similar positive development was seen in reactions to errors.

Intermediate-term Developments We observed a decrease in the mastery orientation of the participants of the bridging course and a stable development of their performance orientation. In the control group, mastery orientation and performance approach orientation remained stable, while performance avoidance orientation developed favorably. In this regard, we note that the initial level of mastery orientation of the participants of the bridging course was higher than that of the control group. By the last measurement point, the levels of mastery orientation of intervention group and control group are comparable. Regarding basic psychological needs, autonomy and competence decreased in both groups; in the intervention group, autonomy decreased significantly more than in the control group. A positive intermediate-term development was seen in social relatedness in the intervention group. By contrast, social relatedness remained stable in the control group. With regard to confidence in learning mathematics at university level, implicit theories showed a stable development in both groups, while self-efficacy decreased in both groups.

In the intervention group, the skills to learn remained stable except for effort regulation and organizational strategies, which developed negatively. By contrast, in the control group, all aspects of the skills to learn developed negatively except for affective-motivational reactions to errors and effort regulation strategies, which were stable.

Discussion

The aim of the research presented in this paper is to assess the impact of an intervention designed to support students at the transition from secondary to tertiary education in STEM fields. The intervention is a bridging course designed to help the participants close gaps in their mathematical knowledge and to foster their motivational beliefs and learning skills. Our study focuses on the development of motivational beliefs and the development of learning skills, as well as their relationship to particular features of the bridging course. Below, we discuss to what degree these features (F1-F6) lead to the desired outcomes (O1-O6) of the bridging course and suggest explanations for the results of our study.

The bridging course aims to promote eagerness to master mathematical concepts and to perform well (O1) by adapting a tutoring strategy (F1) that should encourage students to consolidate their mathematical competencies and close gaps in their prior knowledge. Indeed, the participants exhibit a higher mastery goal orientation at the end of the intervention than at the beginning, which according to university mathematics teachers is an indicator that the intervention has brought about an essential improvement (Pinto & Koichu, 2023). Their performance orientation does not change, possibly due to the fact that the bridging course does not feature assessments except for informal self-checks. Rather, the participants work towards mastery of mathematical concepts that are typically expected of incoming students in STEM fields.

Academic requirements to proceed further in a degree program exert pressure on students and elicit extrinsically motivated behavior in students (Liebendörfer, 2018). By adapting a particular tutoring strategy (F1), the intervention aims to foster confidence to take on academic hurdles (O2). The stable development of implicit theories and the decrease of self-efficacy seen in the participants suggest that the intervention is not able to accomplish this fully in the intermediate term. In combination with the decline in confidence and favorable mindset observed by Code et al. (2016) in a context without a specific intervention, our study underlines how firmly the transition to university challenges students' will to learn. Lankeit and Biehler (2018) report on bridging courses in Germany where the development of self-efficacy in the participants was stable in the short term; specific features of these bridging courses are not mentioned. The slight decrease of self-efficacy might be related to differences between university and school in how mathematics is taught (Rach & Heinze, 2016). This new way of learning and looking at mathematics might unsettle beginning students and undermine their confidence, but, on the other hand, lead to more realistic self-assessment of their current mathematical abilities. The finding of Di Martino et al. (2022a) that students' perception of competence changes on account of higher requirements and unfavorable comparisons with peers might also explain the decrease of self-efficacy in our study. We expect that the significant decrease in self-efficacy in the intermediate term is unrelated to the bridging course. Rather, it might be a consequence of the pressure to fulfil requirements to proceed in the degree. In fact, an intervention at the beginning of a degree program might not be sufficient to prevent feelings of doubt and overwhelming pressure later on, essentially confirming a conclusion of Pinto and Koichu (2023) regarding the period of effectiveness of short-term interventions. To accomplish a stable increase in self-efficacy and confidence, a long-term intervention tailored to students' individual needs might be necessary (Pinto & Koichu, 2023).

To promote psychological well-being at university, which is among the objectives of the bridging course (O3), the intervention features autonomous choice of topic areas (F2), work in small groups together with peers (F3), well-established materials for self-directed learning (F5), and various onboarding activities (F6). Surprisingly, the participants perceive themselves as less autonomous and less competent at the end of the bridging course. The possibility to choose freely which topic area to work on each day and thus to spend several days on the same topic area is used by some; most of the participants, however, proceed through the topic areas in a linear fashion. It is plausible that policies related to the COVID-19 pandemic and respective restrictions in the bridging course had a negative impact on how students perceived their autonomy (e. g., Holzer et al., 2021). This might help explain why, other than in the pilot study where the development of autonomy was stable across all measurement points in both groups, the development of autonomy was negative in this study. A possible explanation for the decrease in perception of competence is that students discover more gaps in their prior knowledge than they are able to close in the bridging course. This, in turn, could be a favorable outcome as the participants start into their degree program with more realistic self-assessment of their competence. The intervention signals to participants the need to catch up early on. For many participants, the bridging course is the first time where they do not perceive themselves as among the top students in mathematics in their peer group, causing them to feel less competent (see also Di Martino et al., 2022a). The results of our study suggest that the design of the bridging course boosts social relatedness among the participants, indicating that the intervention is a key event for establishing social connections at the secondary-tertiary transition.

The negative developments of most aspects of the will to learn seen in both groups suggest that motivational beliefs of students in STEM fields are volatile at the secondary-tertiary transition and that short-term interventions have limited impact on them. By contrast, the participants of the bridging course showed a statistically significant short-term increase in their skills to learn (O4). Even though the skills to learn decrease after the intervention, many aspects remain at a higher level in the intervention group than in the control group in the intermediate term.

The results suggest that an intervention of the design of the mathematics bridging course at hand fosters the establishment of social connections. Strategies regarding effort regulation and organization peak by the end of the intervention and then drop considerably towards the first exam, which suggests that the tutoring strategy of the intervention positively impacts persistence and self-organization in the short term. A similar development is seen in elaboration and metacognitive self-regulatory strategies. This, however, needs further investigation since the measures used in this study were not sufficiently reliable.

To sum up, there is clear indication that the skills to learn develop strongly positively during the intervention and strongly negatively after the intervention. The study of Arco-Tirado et al. (2011) provides empirical support for the assumption that a long-term intervention such as a peer-tutoring program in the first semester can foster cognitive and metacognitive learning skills also after the start of a degree program. The benefits of a long-term intervention are also reported by university mathematics teachers, who, according to a study of Pinto and Koichu (2023), view a tutoring program as the most effective means to support the secondary-tertiary transition. It would therefore be worthwhile to investigate how effective the combination of a bridging course and a tutoring program in the first semester can be.

Implications Many institutions offer effective programs to support students before and during the first semester of their degree programs. Based on the aforementioned works and the findings of our study, we propose that support programs should be accessible throughout the transition period.

Considering that students who do not complete such programs also tend to perform worse (see, e.g., Shao et al., 2010), the design of support programs should not only focus on subject-related competencies but also on learning strategies and actively foster motivation and perseverance.

Due to our first promising results we recommend the inclusion of pre-service teachers as tutors in support programs at the secondary-tertiary transition and to adapt a tutoring strategy with theoretical inputs as well as assisted self-directed and peer learning.

It would be interesting to study the motives of beginning students to participate or not to participate in support programs. A more extensive study might be able to connect the development of learning skills and of motivation to student success.

Limitations The self-selection of students into the bridging course and into the study might produce a systematic effect. Students who dropped out early from the respective degree programs were not reached at the last measurement point. Checking for systematic effects through the analysis of control variables suggests, on the one hand, that students who enrolled in the bridging course achieved slightly lower in the mathematics school leaving exam than those who did not enroll. On the other hand, control variables indicate that students with better grades in the school-leaving exam are more likely to remain in their degree programs. We did not observe a significant initial difference in the other control variables, which suggests that the systematic effects are limited.

Despite these limitations, this work adds an extensive evidence-based contribution that addresses the impact of participation in a mathematics bridging course on learning skills and motivation. It serves as a reference for future such studies.

Appendix

Hypotheses

It was assumed that the intervention had a positive short-term impact and a stabilizing intermediate-term impact. In contrast, we hypothesized that students in the control group would show unfavorable intermediate-term developments. Table 6 provides an overview of our hypotheses.

Table 6 Hypotheses regarding short-term and intermediate-term developments in the constructs among the intervention group (IG), the control group (CG), and between the IG and the CG

Construct	Within groups			Between groups
	IG (short term)	**IG (intermediate term)**	**CG**	**IG vs. CG**
Achievement goals				
Mastery approach	H1a (+)	H1d (=)	H1g (-)	H1j (>)
Performance approach	H1b (+)	H1e (=)	H1h (-)	H1k (>)
Performance avoidance	H1c (-)	H1f (=)	H1i (+)	H1l (<)
Basic psychological needs				
Autonomy	H2a (+)	H2d (=)	H2g (-)	H2j (>)
Competence	H2b (+)	H2e (=)	H2h (-)	H2k (>)
Social relatedness	H2c (+)	H2f (=)	H2i (-)	H2l (>)
Implicit theories	H3a (+)	H3b (=)	H3c (-)	H3d (>)
Reactions to errors				
Action adaptivity	H4a (+)	H4c (=)	H4e (-)	H4g (>)
Affective-motivational adaptivity	H4b (-)	H4d (=)	H4f (+)	H4h (<)
Self-efficacy	H5a (+)	H5b (=)	H5c (-)	H5d (>)
Self-regulated learning				
Effort regulation				
Elaboration				
Help seeking	H6a (+)	H6e (=)	H6i (-)	H6m (>)
Metacognitive self-regulation	H6b (+)	H6f (=)	H6j (-)	H6n (>)
Organization	H6c (+)	H6g (=)	H6k (-)	H6o (>)
Peer learning	H6d (+)	H6h (=)	H6l (-)	H6p (>)
Control variables				
Age				H7a (=)
Gender				H7b (=)
Grade (mathematics school leaving exam)				H7c (=)
Parents' school qualification				H7d (=)
Year of qualification for university				H7e (=)

Hypothesized increases in the outcome variables are marked with “+”, decreases with “-“, and hypothesized stable developments are marked with “=”; hypothesized equality of control variables in the IG and in the CG is marked with “=”; hypothesized higher increases in the IG than in the CG are marked with “>”, the corresponding higher decreases with “<”

Results of the Pilot Study

In this section, we report the detailed results of the pilot study regarding developments in the intervention group (Table 7), developments in the control group (Table 8), and developments across the whole sample as well as comparisons between the developments in the intervention group and the control group (Table 9).

Sample Details

Participants Per Measurement Point

Imputation

The statistical power of the sample was increased by imputing missing data using *SPSS Statistics 26* and following the procedure of Rubin (1987). First, we imputed single items that had not been answered by the respondents. Second, we imputed all missing values of responses to outcome variables from participants of the intervention group who had participated in MP3 but had not participated in either MP1 or MP2. Thereby, the missing data in MP1 were imputed for the four participants who had participated in MP2 and MP3, and the missing data in MP2 were imputed for the six participants who had participated in MP1 and MP3 (see Table 10). Thus, the number of datasets with complete data across all measurement points in the intervention group could be increased from 33 to 43.

Checks for Selection Effects

When recruiting participants for the studies, a sample was taken from the population of incoming students in STEM fields. The intervention group consists of students who voluntarily participated in the bridging course and in the study. Therefore, a possible selection effect must be taken into account. We used independent samples *t*-tests to test our hypotheses that there are no statistically significant initial differences in the control variables (see Appendix "Hypotheses") between the intervention group and the control group (H7a-e). Moreover, the categorical control variables were tested for initial differences using chi-square tests. By "initial" we mean that in each case the measurements of the first measurement point in each group, i. e., MP1 in the intervention group and MP2 in the control group, are examined.

We also tested for initial differences between those students who participated at the last measurement point of our studies and those who did not. This is to determine a potential bias that might originate from students dropping out of their degrees early on.

As shown in Table 11, no statistically significant initial differences could be detected except for mastery approach goals and performance approach goals, which were higher in the intervention group than in the control group, and perceived competence and self-efficacy, which were lower in the intervention group. As for the

Table 7 Pilot study: developments in the intervention group

Construct	MP1	MP2	MP3	Within-subject effects				Short-term development				Intermediate-term development			
	M (SD)	M (SD)	M (SD)	F	df	df_R	p	F	df_R	p	r	F	df_R	p	r
Achievement goals															
Mastery approach	5.30 (.86)	5.64 (.42)	5.40 (.56)	3.314	1.495[a]	49.335[a]	.058	5.151	33	.030	**.37**	.416	33	.523	.11
Performance approach	3.37 (.93)	3.59 (1.21)	3.55 (1.16)	.792	1.857[b]	61.265[b]	.449	1.882	33	.179	.23	.697	33	.410	.14
Performance avoidance	3.86 (.88)	4.35 (.98)	3.96 (1.18)	3.440	1.864[b]	61.512[b]	.041	7.938	33	.008	**.52**	.186	33	.669	.09
Basic psychological needs															
Autonomy	4.11 (.83)	4.24 (.89)	4.02 (.89)	1.110	1.617[b]	32.335[b]	.330	1.649	20	.214	.28	.317	20	.580	.13
Competence	4.43 (.84)	4.41 (.80)	3.90 (.76)	7.763	1.960[b]	39.206[b]	.002	.012	20	.913	.03	9.007	20	.007	**.56**
Social relatedness	4.62 (.86)	4.56 (.80)	4.67 (.74)	.378	1.658[b]	33.160[b]	.649	.488	20	.493	.15	.097	20	.759	.07
Implicit theories	4.63 (.85)	5.05 (1.02)	4.94 (.95)	3.822	1.334[a]	42.682[a]	.046	4.357	32	.045	**.35**	3.309	32	.053	.33
Reactions to errors															
Action adaptivity	4.98 (.65)	5.25 (.61)	4.98 (.73)	3.341	2.000	64.000	.042	4.777	32	.036	**.36**	<.001	32	.988	<.01
Affective-motivational adaptivity	3.61 (1.04)	3.31 (.90)	4.07 (1.19)	7.041	2.000	64.000	.002	3.048	32	.112	.28	7.028	32	.046	**.34**
Self-regulated learning															
Peer learning	4.22 (.84)	5.14 (.72)	4.53 (1.22)	11.805	1.722[b]	55.094[b]	<.001	42.205	32	<.001	**.75**	2.171	32	.150	.25

Figures in boldface reflect statistical significance at the .05 level

M mean value, *SD* standard deviation, *F* ANOVA test statistics, *df* degrees of freedom, df_R df of residuals, *p* significance, *r* Pearson correlation coefficient

[a]Greenhouse-Geisser correction

[b]Huynh-Feldt correction

Table 8 Pilot study: developments in the control group

Construct	MP2	MP3	Change			
	M (SD)	M (SD)	*t*	df	p	r
Achievement goals						
Mastery approach	5.46 (.54)	5.24 (.74)	-2.722	88	.008	**.28**
Performance approach	3.72 (1.18)	3.30 (1.28)	-3.817	88	<.001	**.38**
Performance avoidance	4.01 (1.25)	3.62 (1.37)	-3.664	88	<.001	**.36**
Basic psychological needs						
Autonomy	4.04 (.86)	4.05 (.82)	.150	87	.881	.02
Competence	4.26 (.82)	4.01 (.84)	-2.979	87	.004	**.30**
Social relatedness	4.44 (.98)	4.42 (1.05)	-.316	87	.752	.03
Implicit theories	5.09 (.88)	5.13 (.90)	.411	87	.682	.04
Reactions to errors						
Action adaptivity	5.05 (.78)	4.80 (.95)	-2.748	87	.007	**.28**
Affective-motivational adaptivity	3.94 (1.23)	3.98 (1.21)	.302	87	.764	.03
Self-regulated learning						
Peer learning	4.24 (1.00)	4.32 (1.33)	.825	87	.412	.09

Figures in boldface reflect statistical significance at the .05 level

M mean value, *SD* standard deviation, *t* *t*-test statistics, *df* degrees of freedom, *p* significance, *r* Pearson correlation coefficient

control variables, the intervention group had worse grades in the written school-leaving exam in mathematics and the parents of students of the intervention group had a higher formal qualification. All these statistically significant differences have a small effect size.

There was a statistically significant association between participation in the bridging course and whether or not students were studying full-time, $\chi^2(1) = 6.20$, $p = .013$. Based on the odds ratio, this seems to represent the fact that students who were studying full-time were twice as likely to participate in the bridging course as students who were studying part-time. Whether or not students' family members had studied at university does not seem to influence participation in the bridging course, $\chi^2(1) = 1.53$, $p = .216$. Gender, $\chi^2(1) = .66$, $p = .415$, prior experience studying at university, $\chi^2(1) = .03$, $p = .872$, and caring duties, $\chi^2(1) = 1.30$, $p = .254$, do not seem to influence participation in the bridging course either. As the effect sizes of statistically significant differences are small, we view the groups as having a comparable starting point for their university studies.

As can be seen in Table 12, students who participated in MP3 had statistically significantly higher psychological well-being in terms of their perceived autonomy, competence, and social relatedness. Moreover, action-adaptive reactions to errors, self-efficacy, and effort regulation were higher among the participants in MP3. While all these differences have small effect sizes except for autonomy (medium effect size), the

Table 9 Pilot study: intermediate-term developments across all participants (MP) and interaction effects between intermediate-term developments and participation in the bridging course (MP * GROUP)

Construct	PRE	POST	MP				MP * GROUP			
	M (SD)	M (SD)	F	df_R	p	r	F	df_R	p	r
Achievement goals										
Mastery approach	5.41 (.64)	5.29 (.69)	.491	121	.485	.06	3.889	121	.051	.18
Performance approach	3.62 (1.13)	3.37 (1.25)	1.115	121	.285	.10	7.287	121	.008	**.24**
Performance avoidance	3.97 (1.16)	3.71 (1.32)	1.759	121	.187	.12	4.857	121	.029	**.20**
Basic psychological needs										
Autonomy	4.22 (.78)	4.02 (.82)	6.396	119	.013	**.23**	.001	119	.972	<.01
Competence	4.17 (.79)	4.00 (.82)	5.386	119	.022	**.21**	.599	119	.441	.07
Social relatedness	4.54 (.84)	4.47 (.98)	.216	119	.643	.04	1.459	119	.229	.11
Implicit theories	4.96 (.89)	5.08 (.91)	3.934	119	.050	**.18**	2.432	119	.122	.14
Reactions to errors										
Action adaptivity	5.03 (.75)	4.85 (.90)	2.280	119	.134	.14	2.215	119	.139	.14
Affective-motivational adaptivity	3.85 (1.19)	4.00 (1.20)	4.443	119	.037	**.19**	3.261	119	.073	.16
Self-regulated learning										
Peer learning	4.24 (.95)	4.38 (1.30)	2.474	119	.118	.14	.886	119	.349	.09

Figures in boldface reflect statistical significance at the .05 level

M mean value, *SD* standard deviation, *F* ANOVA test statistics, df_R degrees of freedom of residuals, *p* significance, *r* Pearson correlation coefficient

Table 10 Number of participants of the intervention group (IG) and of the control group (CG) and their participation in the three measurement points

MP1	MP2	MP3	Pilot study		Main study	
			IG	CG	IG	CG
Yes	No	No	42	-	84	-
Yes	Yes	No	22	-	105	-
Yes	No	Yes	5[a]	-	6[a]	-
Yes	Yes	Yes	22	-	33	-
No	Yes	No	19	230	54	244
No	No	Yes	13	65	7	50
No	Yes	Yes	7[a]	89	4[a]	92
Overall			130	384	293	386

[a]Data of missing measurement point were imputed

Table 11 Tests for initial differences between the intervention group (IG) and the control group (CG)

Construct/Scale	IG		CG		Equality of means			
	M	SD	M	SD	*t*	df	p	r
Achievement goals								
Mastery approach	5.38	.66	5.19	.77	3.111	539.41	.002	**.13**
Performance approach	3.46	1.30	3.24	1.20	2.065	566	.039	**.09**
Performance avoidance	3.83	1.35	3.61	1.34	1.879	566	.061	.08
Basic psychological needs								
Autonomy	5.03	1.06	5.19	.96	-1.799	566	.073	.08
Competence	4.70	.95	4.92	.92	-2.715	566	.007	**.11**
Social relatedness	3.94	1.40	3.88	1.42	.525	566	.600	.02
Implicit theories	5.10	.78	5.03	.82	1.006	566	.315	.04
Reactions to errors								
Action adaptivity	4.69	1.01	4.78	.83	-1.019	431.46	.309	.05
Affective-motivational adaptivity	3.74	1.20	3.78	1.15	-.421	566	.674	.02
Self-efficacy	4.46	1.08	4.67	.95	-2.482	454.39	.013	**.12**
Self-regulation								
Effort regulation	4.40	.92	4.31	1.05	1.058	566	.291	.04
Elaboration	4.14	1.53	3.93	1.67	1.527	566	.127	.06
Help seeking	3.45	1.23	3.31	1.13	1.380	466.40	.168	.06
Metacognitive self-regulation	4.34	1.31	4.29	1.39	.449	566	.762	.02
Organization	3.95	1.09	3.88	1.21	.716	566	.475	.03
Peer learning	3.40	1.12	3.43	1.25	-.224	528.27	.823	.01
Control variables								
Age	20.56	5.67	20.55	5.45	.012	658	.990	<.01
Grade (mathematics school leaving exam)	2.26	1.11	2.05	1.04	2.195	439.02	.029	**.10**
Parents' formal qualification	1.72	1.07	1.94	1.21	-2.472	660	.014	**.10**
Year of qualification for university	2019.04	5.68	2019.29	4.34	-.648	649	.517	.03

Figures in boldface reflect statistical significance at the .05 level

M mean value, *SD* standard deviation, *t* *t*-test statistics, *df* degrees of freedom, *p* significance, *r* Pearson correlation coefficient, $N_{IG} = 232$, $N_{CG} = 336$

Table 12 Tests for initial differences between participants who participated in MP3 and those who did not

Construct/Scale	MP3: yes		MP3: no		Equality of means			
	M	SD	M	SD	*t*	df	p	r
Achievement goals								
Mastery approach	5.25	.86	5.27	.68	.189	566	.850	.01
Performance approach	3.34	1.25	3.33	1.24	.162	566	.871	.01
Performance avoidance	3.73	1.35	3.69	1.35	-.267	566	.789	.01
Basic psychological needs								
Autonomy	5.41	.76	5.04	1.05	-4.559	309.71	<.001	**.25**
Competence	5.09	.85	4.75	.95	-3.753	566	<.001	**.16**
Social relatedness	4.12	1.32	3.84	1.44	-2.009	566	.045	**.08**
Implicit theories	5.03	.77	5.07	.82	.444	566	.657	.02
Reactions to errors								
Action adaptivity	4.91	.89	4.69	.90	-2.427	566	.016	**.10**
Affective-motivational adaptivity	3.82	1.23	3.74	1.16	-.694	566	.488	.03
Self-efficacy	4.78	.91	4.52	1.03	-2.607	566	.009	**.11**
Self-regulation								
Effort regulation	4.59	.95	4.27	1.00	-3.328	566	.001	**.14**
Elaboration	4.23	1.55	3.94	1.63	-1.834	566	.067	.08
Help seeking	3.25	1.17	3.40	1.17	1.306	566	.192	.05
Metacognitive self-regulation	4.50	1.39	4.25	1.35	-1.851	566	.065	.08
Organization	4.04	1.23	3.87	1.14	-1.548	566	.122	.06
Peer learning	3.50	1.28	3.39	1.17	-.916	566	.360	.04
Control variables								
Age	20.38	5.30	20.62	5.64	.506	659	.613	.02
Grade (mathematics school leaving exam)	1.76	.99	2.28	1.07	5.372	297.39	<.001	**.30**
Parents' school qualification	1.84	1.14	1.85	1.17	.056	661	.956	<.01
Year of qualification for university	2019.29	5.00	2019.14	4.96	-.359	650	.720	.01

Figures in boldface reflect statistical significance at the .05 level

M mean value, *SD* standard deviation, *t* *t*-test statistics, *df* degrees of freedom, *p* significance, *r* Pearson correlation coefficient, $N_{MP3\_yes} = 135$, $N_{MP3\_no} = 433$

students who participated in MP3 had better grades in the written final mathematics examination (medium effect size). This suggests that the students with better grades at school are also more likely to remain in their degree program at university.

Gender, $\chi^2(1) = .15$, p = .696, prior experience studying at university, $\chi^2(1) =.10$, p = .750, experiences at university of family members, $\chi^2(1) = .98$, p = .322, caring duties, $\chi^2(1) = 2.17$, p = .141, and whether or not students were studying full-time, $\chi^2(1) = .40$, p = .530, seem not to have influence on participating in MP3.

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Data Availability The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Informed Consent Informed consent was obtained from all subjects involved in the study.

Competing Interests The bridging course investigated in this work is organized by Michael Eichmair with help from Martin Mayerhofer. The authors have no competing financial interests to declare that are relevant to the content of this article.

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