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From School to University: Trends and Gender Differences in the Motivation to Learn Mathematics

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Table of Contents

Preface

My education has afforded me many opportunities, for which I am very grateful.

Thank you, Univ.-Prof. Michael Eichmair, PhD, for your continued support starting in the fourth semester of my university education, for sparking my interest in scientific research, and for supervising both my master thesis and my doctoral thesis with great care. The project *Mathematik macht Freude* you have created has provided the framework in which I carried out my research. I am grateful for your support to pursue my passion for teaching at school alongside my doctorate. Your style of supervision has fostered a scientific way of thinking in me, which has also profoundly shaped my personality.

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Zusammenfassung

Diese Dissertation umfasst vier Studien, die motivationale Aspekte des Mathematiklernens bei Jugendlichen untersuchen. Die erste Studie erforscht Unterschiede in der Sekundarstufe II zwischen Schulstufen und Geschlechtern hinsichtlich der Absicht, eine Karriere im Bereich Mathematik, Informatik, Naturwissenschaften und Technik (MINT) einzuschlagen. Die zweite Studie untersucht Geschlechterunterschiede in der Lernmotivation in Mathematik am Übertritt zwischen Schule und Hochschule. Die dritte Studie identifiziert unterschiedliche Muster in der Entwicklung der Lernmotivation in Mathematik während dieses Übertritts. Die vierte Studie untersucht die Auswirkungen einer spezifischen Intervention, die auf die Förderung der Motivation und der Lernkompetenzen von Studienanfänger*innen in Bachelorstudiengängen mit MINT-Bezug abzielt.

Die Studien wurden unter Verwendung von validierten Fragebögen durchgeführt, welche an Schüler*innen österreichischer Allgemeinbildender höherer Schulen sowie an Studierende in MINT-Bachelorstudiengängen an zwei Wiener Universitäten ausgegeben wurden. Die Ergebnisse legen nahe, dass Geschlechterunterschiede bei MINT-Karriereabsichten während der Sekundarstufe II konsistent zugunsten von männlichen Schülern ausfallen. Hinsichtlich der Lernmotivation in Mathematik während des Übertritts zwischen Schule und Hochschule sind Geschlechterunterschiede zugunsten männlicher Schüler feststellbar. Eine nähere Untersuchung zeigte, dass Studienanfänger*innen einem von vier unterschiedlichen motivationalen Profilen zugeordnet werden können. Nur die Studierenden mit dem vorteilhaftesten Motivationsprofil sind in der Lage, ihre günstige Motivationslage aufrechtzuerhalten, während die Motivation der anderen Studierenden erheblich abfällt. Eine kurzfristige Intervention, die darauf abzielt, Motivation und Lernkompetenzen von Studienanfänger*innen in Bachelorstudiengängen mit MINT-Bezug zu fördern, zeigte, dass diese Lernkompetenzen sowie einige motivationale Aspekte am Beginn des ersten Semesters gesteigert werden konnten. Die Intervention war jedoch nicht imstande, die Motivation der Studierenden über die unmittelbare Phase des Übertritts hinaus zu steigern.

Die Ergebnisse dieser Studien zeigen, dass Geschlechterunterschiede zugunsten von Schülern und Studenten im MINT-Bereich anhaltend sind und während der Sekundarstufe II und des Übertritts in den tertiären Bereich verstärkt werden. Die Ergebnisse zeigen auch, dass ein vorteilhaftes Motivationsmuster am Beginn der tertiären Bildung für einen erfolgreichen Übertritt günstig ist. Aus diesem Grund sollte die Förderung der Motivation ein integraler Bestandteil sowohl in der Sekundarstufe als auch in der Tertiärbildung sein.

Abstract

This dissertation comprises four studies that examine motivational aspects related to learning mathematics in adolescents. The first study investigates differences by gender and age cohorts in the intentions of upper secondary school students to pursue a career in the fields of science, technology, engineering, and mathematics (STEM). The second study explores gender differences in the motivation to learn mathematics during the secondary-tertiary transition into STEM bachelor programs. The third study identifies distinct patterns in the development of the motivation to learn mathematics during this transition. The fourth study examines the impact of a specific intervention program designed to foster the motivation and learning skills of beginning students in STEM bachelor programs.

The studies were conducted using validated questionnaires administered to Austrian academic upper secondary school students and to students in STEM bachelor programs at two universities in Austria. The results suggest that gender differences in STEM career intentions during upper secondary school are consistently in favor of male students. Regarding the motivation to learn mathematics, gender differences in favor of male students are evident during the secondary-tertiary transition into STEM bachelor programs. A closer examination revealed that beginning students can be assigned to one of four distinct motivational profiles. Only the students in the most adaptive profile are able to maintain their favorable motivational state, while other students experience a considerable decline in motivation. A short-term intervention aimed at fostering the motivation and learning skills of beginning students in STEM bachelor programs was shown to boost learning skills and some aspects of motivation at the beginning of the first semester. However, the intervention did not enable students to maintain their motivation beyond the transition period.

The results of these studies show that gender differences in favor of male students persist in the STEM domain and that they are reinforced during upper secondary education and the transition to university. The results also show that having a beneficial motivational pattern at the beginning of one’s tertiary education is an asset for mastering the secondary-tertiary transition. Therefore,

motivational support should be an integral part of education both at the secondary and tertiary level.

Introduction

A great challenge for today's decision makers—and no doubt also tomorrow's—is to accomplish economic prosperity and social stability in a way that is also environmentally sustainable. Equally great is the responsibility of scientists to inform society on the whole and politicians in particular to steer them away from anecdotal evidence, preconceptions, and populistic narratives.

While primary and secondary education ought to hardwire a basic acceptance of science in all citizens, the role of tertiary education is to impart the specialized knowledge and skills required of an innovative and competitive workforce. In some domains, the number of citizens with higher education is much behind economic needs. This is especially true of the domain of science, technology, engineering, and mathematics (STEM).

An urgent issue to resolve in this context are the high dropout rates in STEM bachelor programs. This dissertation contributes to our understanding of the transition from secondary education into such programs. Specifically, the four research articles in this dissertation investigate differences by gender and age cohorts in adolescents' intentions to pursue a STEM career during upper secondary education as well as the development of learning skills and the motivation to learn mathematics of young adults in the course of their transition from secondary school into STEM bachelor programs.

Formation of STEM career intentions during childhood and adolescence

The formation of career intentions has been the subject of extensive scientific research. Much of this research has been conducted with a focus on the STEM domain, owing to the shortage of STEM specialists and efforts to attract more students to this domain. Social-cognitive measures have been found to be highly predictive of career choices (e.g., Li et al., 2024; Woo et al., 2023), making *social cognitive career theory* (Lent et al., 1994) a widely-used framework to study career intentions. Departing from *social cognitive theory* as proposed by Bandura (1986), this framework considers self-efficacy, outcome expectations, and goals as key factors for the formation of career intentions.

Career intentions start to develop early on in childhood and may change repeatedly over time (Li et al., 2024). The model of *circumscription and compromise* put forth by Gottfredson (1981) describes the development of career intentions in children and adolescents. It considers gender, social class background, intelligence, vocational interests, competencies, and values as the most relevant factors for this development. More precisely, these factors are proposed to shape occupational aspirations in four stages (Gottfredson, 1981): At the age of 3 to 5 years, children become aware of the difference between childhood and adulthood as well as the roles of children and adults therein. At 6 to 8 years, children develop a sense of gender roles and exclude professions that are traditionally viewed as incompatible with their gender. At 9 to 13 years, the concepts of social class and ability start to determine children's behavior and expectations, leading them to exclude occupations of insufficient reputation. Starting at 14 years, adolescents increasingly take into account their own feelings and self-perceived abilities, leading them to eliminate career options that seem to them to exceed their abilities. After this progressive narrowing or *circumscription* of career options, considerations of job prospects cause adolescents to *compromise* and expand the range of careers they view as suitable for themselves.

While personal interests and self-efficacy guide the career choices of adolescents, gender roles conveyed by their social environment are a significant confining factor that leads to a considerable imbalance in favor of men in STEM fields (Holmes et al., 2018; van Tuijl & Walma van der Molen, 2016). Van Tuijl and Walma van der Molen (2016) emphasize that children should be made aware of STEM career prospects from an early age. Parents and teachers should be familiar with job prospects in STEM and should have a basic understanding of how children and adolescents explore their career options so that they can impart this knowledge on learners and guide them away from confining stereotypes.

The model of Gottfredson (1981) draws a clear picture of how the developmental processes that start in early childhood and continue into adolescence influence the formation of career options. It provides a sound incentive to parents and other stakeholders in education to introduce children to the wide range of activities in the STEM domain early on. However, this model leaves open the question of whether the resulting career intentions of youths remain stable in late adolescence, when decisions about future educational or occupational career paths are made. Research goal 1 of this dissertation is to examine the development of STEM career intentions in the course of upper secondary school.

Development of the motivation to learn mathematics in tertiary education

The willingness of beginning students in STEM bachelor programs to study mathematics on an advanced level is typically high (Di Martino et al., 2023). The expectation to succeed in their programs and the value they place on mathematics provide incentives to students to engage in learning activities. This general mechanism is described systematically in *expectancy-value theory* (Eccles, 1983), which considers individuals' *expectancy* of their success and the *value* they place on the anticipated outcomes of their learning efforts as the central variables. According to this theory, these variables are indicative of achievement motivation, performance, and persistence, and guide achievement-related choices.

Despite their initially high motivation, many students in STEM bachelor programs quit their degrees early on (Heublein et al., 2017). Major challenges that have been linked to early dropout include the introduction of new mathematical concepts and ways of thinking (Gueudet, 2008; Thomas et al., 2015) as well as elevated institutional expectations and problems in performance (Gueudet, 2008; Heublein et al., 2017). In their review of scientific research on the matter, Scherrer and Preckel (2019) have found a general decline in several motivational aspects of learners over time and called for domain-specific investigation of the development of motivational constructs.

Research goal 2 of this dissertation is to examine how students' motivation to engage in mathematics develops at the transition from secondary school to tertiary education in STEM.

Interventions at the secondary-tertiary transition

Following Gottfredson (1981), early involvement of children in STEM activities and guidance by parents and teachers to help them stay clear of gender stereotypes fosters the development of STEM career intentions. To help young adults follow through with STEM career intentions, interventions to support them at the secondary-tertiary transition into STEM bachelor programs are needed. Geisler et al. (2023) emphasize the importance of interventions that foster interest and improve the self-concept of learners before the start of bachelor programs to help them keep up their interest and self-concept during the first weeks at university.

Research goal 3 of this dissertation is to examine the impact of a mathematics bridging course with specific features on the motivation and the skills to self-regulate one's learning behavior of beginning students in STEM bachelor programs.

Research goals of this dissertation

This dissertation contributes to our understanding of how intentions of upper secondary school students to enter bachelor programs in STEM fields differ by gender and age cohorts in the first place, of how the motivation of beginning university students in STEM bachelor programs develops, and of how tailored support programs at the secondary-tertiary transition into STEM bachelor programs impact students during their first weeks at university. These questions are posed before the background of high dropout rates in STEM bachelor programs as well as great gender differences in enrollment and success in favor of male students.

Specifically, the broader research goals (RG) of this dissertation are to

(RG1) identify how intentions to pursue a STEM career differ by gender and age cohorts in upper secondary school;

(RG2) identify how motivation develops at the transition from secondary school to STEM bachelor programs;

(RG3) identify the impact of support programs on the motivation of beginning university students in STEM bachelor programs.

To this end, several studies were conducted in this dissertation, for which the research goals were operationalized as follows.

(RQ1) How do students' aspirations to enroll in a STEM bachelor program differ by gender and age cohorts in upper secondary education?

(RQ2) How does the motivation of beginning STEM field students develop in the course of the secondary-tertiary transition? Are there gender differences?

(RQ3) How do the motivational patterns of beginning STEM field students develop in the course of the secondary-tertiary transition?

(RQ4) What impact does a mathematics bridging course have on the motivation and the learning skills of beginning students in STEM bachelor programs?

The following four research articles are based on these research goals and provide answers to the research questions, making them the main contribution of this dissertation.

Mayerhofer, M., Weinhandl, R., Lüftenegger, M., & Eichmair, M. (submitted). Differences in STEM career intentions by gender and age cohorts during upper secondary education.

Mayerhofer, M., Eichmair, M., & Lüftenegger, M. (2023). Trends in expectancy for success and value beliefs at the secondary-tertiary transition into STEM fields. In Drijvers, P., Csapodi, C., Palmér, H., Gosztonyi, K., & Kónya, E. (Eds.), *Proceedings of the Thirteenth Congress of the European Society for Research in Mathematics Education (CERME13)* (pp. 2543-2460). Alfréd Rényi Institute of Mathematics and ERME. https://hal.science/CERME13/hal-04410144v1

Mayerhofer, M., Lüftenegger, M., & Eichmair, M. (2024). The development of mathematics expectancy-value profiles during the secondary-tertiary transition into STEM fields. *International Journal of STEM Education, 11*, Article 31. https://doi.org/10.1186/s40594-024-00491-6

Mayerhofer, M., Lüftenegger, M., & Eichmair, M. (2023). Impact of a Mathematics Bridging Course on the Motivation and Learning Skills of University Students. *International Journal of Research in Undergraduate Mathematics Education*. https://doi.org/10.1007/s40753-023-00224-0

Below, these research articles are presented in the form of extended abstracts followed by the articles submitted to or published by scientific journals.

Research articles of this dissertation

Research article 1: Differences in STEM career intentions by gender and age cohorts during upper secondary education

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Publication status

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Supervision: Michael Eichmair, Marko Lüftenegger

Research article 1 aims to identify how intentions to pursue a STEM career differ by gender and age cohorts in upper secondary school (RG1).

Impressed by assumptions significant others impose about their talents as well as by gender stereotypes, youths begin to discard potential options for their future education and career paths early on (Holmes et al., 2018; van Tuijl & Walma van der Molen, 2016). Gender differences in school performance as well as in educational and career choices may well be rooted in such external influences, especially in STEM fields.

Research article 1 focuses on the differences seen in STEM career intentions by gender and age cohorts in upper secondary education. We used *social cognitive career theory* (SCCT) as a theoretical basis to examine these differences. This framework considers *self-efficacy*, *outcome expectations*, and *goal representations* as indicative of career intentions (Lent et al., 1994). It is well known that motivational aspects typically decline during adolescence (Scherrer & Preckel, 2019). As proposed by *stage-environment fit theory* (Eccles et al., 1993), this may be explained by a mismatch between the social environment of adolescents on the one hand and their needs on the other hand. We used this theory to guide our interpretation of the results.

We conducted a research project among students in academic upper secondary schools in Austria. All such schools were contacted and invited to participate in the study. Research article 1 reports the results from a study conducted within this research project with a sample of 5474 students from 137 schools. The sample was representative of the gender distribution, the proportion of students in public and in private schools, and the proportion of students in each grade in Austrian academic upper secondary schools. In line with SCCT, the main focus of this study lies on self-efficacy, outcome expectations, and achievement goals in the context of learning mathematics, along with contextual socio-demographic variables. Analysis of variance was used to identify differences in career intentions by gender and age cohorts and differences between those who strive for a STEM career and those who do not.

The results show that self-efficacy is higher towards the end of upper secondary education while outcome expectations are slightly lower. The various goal-related beliefs surveyed in our study are not uniform, with some aspects showing more favorable (lower work-avoidance goals) and others less favorable (lower mastery approach goals, lower performance approach goals) manifestations in the later grades of upper secondary education. In contrast to what could be expected based on stage-environment fit theory, self-efficacy is found to be higher towards the end of upper secondary education. The results suggest that the confidence of students to master mathematics is boosted towards the end of upper secondary school, where practice of already familiar concepts with an eye towards the centralized school leaving exam usually takes priority over introducing new material. The examination of gender differences sheds light on the mixed results in the overall sample: Mathematics self-efficacy is higher in the later grades only among male students; outcome expectations are lower in the later grades only among female students; mastery goals are initially higher among male students and ultimately higher among female students; and work avoidance goals are ultimately lower only among male students. It should be noted that the effect sizes are small throughout. Yet, all identified gender differences are in favor of male students. This suggests that gender differences developed early on are maintained—if not to some degree reinforced—during upper secondary education. The large differences between those with STEM aspirations and those without found in the data confirm that SCCT constructs do indeed indicate STEM career intentions. Also, the substantial such differences already seen in grade 9 shows that career intentions are, for the most part, formed out at the beginning of upper secondary education.

To conclude, students' intentions in upper secondary education to enroll in a STEM bachelor program after graduation are not uniform across grades and gender. However, when breaking the differences down by gender, the differences appear to be in favor of male students. These findings highlight the detrimental effects that prevailing gender stereotypes have on STEM career intentions of female students. This is a mandate for stakeholders in education to provide female students with additional opportunities for mastery experiences. Furthermore, female role models can raise awareness and confidence that women can succeed in professions traditionally dominated by men and serve as a source of inspiration for the goals that female students set for themselves.

Differences in STEM career intentions by gender and age cohorts during upper secondary education

The question of how to imbue students with a keen, enduring interest in the fields of science, technology, engineering, and mathematics (STEM) in postsecondary education remains a key topic in the academic and social discourse. Research indicates that the educational environment strongly influences career aspirations. Studies based on stage-environment fit theory show that the match between learner needs and the affordances of their social and educational environment decreases over time, leading to reduced achievement motivation. Our study examines achievement motivation by gender and age during upper secondary school. According to social cognitive career theory, mathematics self-efficacy, outcome expectations, and goal-related beliefs predict postsecondary STEM intentions. This quantitative cross-sectional questionnaire study among upper secondary school students (n = 5474) in 137 Austrian academic secondary schools reveals that mathematics self-efficacy is higher among students closer to graduation, while outcome expectations and achievement goals are lower. Male students exhibit higher self-efficacy and outcome expectations, and more favourable achievement goals. Comparisons between students aspiring to STEM degrees and those choosing other fields indicate that STEM intentions are already clearly formed at the upper secondary level. These results mandate stakeholders in the education system to improve the fit between learning environments and learners' needs.

Keywords: career intentions, educational aspirations, social cognitive career theory

Introduction

Prior studies (e.g., Holmes et al., 2018; van Tuijl & Walma van der Molen, 2016) have identified numerous individual factors, such as self-efficacy and interest, that significantly impact adolescents' choices related to their educational careers. They highlight that external influences such as gender stereotypes or the assumptions significant others express about their potential lead youths to discard some educational and occupational pathways at an early stage of their lives. Once discarded, these pathways are rarely reconsidered as viable options at a later point (Holmes et al., 2018; van Tuijl & Walma van der Molen, 2016). This applies in particular to the fields of science, technology, engineering, and mathematics (STEM fields) (van Tuijl & Walma van der Molen, 2016). There are many works employing established frameworks (e.g., expectancy-value theory, social cognitive career theory) to identify aspects related to the intention to enrol in a STEM degree at university (Fouad et al., 2017; Ketenci et al., 2020; Wang & Degol, 2013). By contrast, the scientific literature lacks studies that examine how the manifestations of these determinants develop in the course of upper secondary education. However, increased mastery, overcoming challenges, and successful advancement to the following school level impact school students' self-efficacy, self-expectations, goal setting, and, therefore, their future educational intentions. In a secondary analysis of data collected in upper-secondary schools in Austria, we investigate the intentions of school students to pursue an educational path in STEM fields at the postsecondary level. Specifically, we explore differences by gender and age cohorts in motivational factors for the context of learning mathematics in the course of upper secondary education and relate them to STEM aspirations.

State of research

There is a substantial body of scientific literature addressing the growing need for a STEM workforce. Many articles highlight concerns about the underrepresentation of women and the overall shortage of individuals pursuing careers in STEM fields. These issues are prevalent across different cultures and regions and are a global challenge. For instance, in the United States, 77 percent of the high school freshmen intending to work in a STEM field later on were male (Holian & Kelly, 2020). Wang et al. (2023) report similar numbers for students in STEM majors in China and highlight that social science majors are in turn dominated by female students. There have been various attempts to explain these inequalities. Wegemer and Eccles (2019) summarise that the gender inequality in STEM careers can be explained by women having stronger altruistic values and a preference for people-oriented careers than men who tend to have less altruistic values and a preference for thing-oriented careers. STEM careers are considered to be rather thing-oriented and only little associated with altruism. Students' occupational altruistic values predicted aspirations for a career in life sciences more strongly than aspirations for STEM careers (Wegemer & Eccles, 2019). Notably, these predictive powers were more strongly pronounced after high school than during high school. STEM fields and disciplines that are typically considered to require particularly high cognitive demands are beset with deeply rooted stereotypes related to gender and innate talent. Exposure to such stereotypes may lead youths to discard at an early stage of their lives the possibility that they would ever pursue a STEM field. Teachers would often contribute to perpetuating societal stereotypes (van Tuijl & Walma van der Molen, 2016).

Astleithner et al. (2023) argue that psychological measures related to self-concept help explain educational choices. In this regard, science/STEM self-efficacy has been found to be significantly related to interest in a science/STEM career (Wang et al., 2023; Zhao et al., 2024). There is scientific evidence that this relation is relatively stable in learners over time (Zhao et al., 2024).

The framework that most research on career intentions and career decisions draws on is *social cognitive career theory*. In our work, we amalgamate social cognitive career theory with stage-environment fit theory to gain insights into the psychological processes that influence career decisions. In the following, we give an overview of these two theories.

Social cognitive career theory

Building on the *social cognitive theory* of Bandura (1986), the *social cognitive career theory* (SCCT; Lent et al., 1994) describes mechanisms that guide and influence academic and career-related choices. Specifically, SCCT focuses on self-efficacy beliefs, outcome expectations, and goal representations as determinants of such choices. Bandura (1986) posited that self-efficacy beliefs significantly impact career choice and development. Within the STEM context, many studies have indeed confirmed the pivotal role of self-efficacy and parental efficacy in developing aspirations: Increased STEM self-efficacy has been found to foster STEM interest and, further, vocational aspirations in STEM fields (e.g., Holmes, 2023). Parental efficacy influences students' self-efficacy in the way that parents of high perceived efficacy would create opportunities that foster a sense of achievement and enjoyment in activities related to specific academic disciplines (Bandura et al., 2001). It has been observed that children of parents with higher education are more likely to engage in out-of-school academic activities (van Rooij et al., 2017) and aspire to achieve at least the same level of education as their parents (Holmes et al., 2018). Additionally, parents' educational expectations and aspirations for their children influence their achievements in school. In a STEM-independent context, parents' expectations and aspirations have been found to correlate positively with their children's academic achievement as long as their aspirations are not unrealistically high (Marsh et al., 2023). Specific to the STEM context, it has been shown that highly educated parents have a more positive attitude towards STEM than less highly educated parents (van Tuijl & Walma van der Molen, 2016). Also, students with parents in a STEM career are more likely to pursue a STEM career themselves (Holmes et al., 2018).

SCCT models a cycle in which activity engagement, feedback, and skill development nurture outcome expectations and the formation of self-efficacy, which, in turn, foster interests. Since interest leads to activity engagement, the cycle restarts. According to SCCT, this cycle is most fluid until late adolescence or early adulthood. The social cognitive mechanisms examined by SCCT are the influences of self-efficacy beliefs, outcome expectations, and goal representations on developing basic career interests (Lent et al., 1994).

Based on SCCT, we consider self-efficacy, outcome expectations, and goal-related beliefs in the context of learning mathematics as indicative of intentions to pursue a STEM field degree at university. We capture differences by gender and age cohorts in these mechanisms during upper secondary education and control for educational aspirations.

Self-efficacy is a context-specific construct broadly defined as the 'beliefs in one's capabilities to organise and execute the courses of action required to manage prospective situations' (Bandura, 1995, p. 2). Bandura stresses the importance of self-efficacy in determining a person's motivational and affective states as well as their choices of action, arguing that such states or choices would be more strongly influenced by subjective beliefs than by factual knowledge. People with high self-efficacy exhibit increased effort, high perseverance, and high resilience (Bandura, 1995). For educational and career decisions, self-efficacy for mathematics and science has been found to be a strong predictor for choosing a STEM field major in college (Bandura et al., 2001; Hackett, 1995; Sahin et al., 2023). However, results in this regard are diverse, with other studies not having identified a link between self-efficacy and STEM career intentions (e.g., Navarro et al., 2007). It should be noted that some studies focus on mathematics self-efficacy (e.g., Pajares, 2005), while others more broadly measure science self-efficacy (e.g., Byars-Winston et al., 2010) or cover both mathematics and science self-efficacy with one construct (e.g., Navarro et al., 2007). This work focuses on mathematics self-efficacy due to its high relevance for all STEM fields.

Bandura et al. (2001) found that children's academic aspirations are affected directly both by their academic and social efficacy as well as by the academic aspirations their parents have for them. Prior studies have consistently found male students to have higher mean levels of mathematics self-efficacy than female students (Arens et al., 2022; Pajares, 2005; Sahin et al., 2023).

According to Bandura (1986), social persuasion is one of the key sources of self-efficacy. The effect on mathematics self-efficacy of social persuasion through encouragement taken from significant others has been found to decrease in female students and increase in male students with age (Mozahem et al., 2021). The mathematics self-concept, a construct strongly related to mathematics self-efficacy, has been found to decrease with age; gender gaps in favour of male students were found to remain stable over time (Nagy et al., 2010).

Outcome expectations are the 'imagined consequences of performing particular behaviors' (Lent et al., 1994, p. 83). In the context of academic aspirations, outcome expectations may refer to physical outcomes such as prospective income, to social outcomes such as the esteem of a specific qualification among significant others, or to self-evaluative outcomes such as satisfaction with activities related to the chosen field of study (Lent et al., 1994).

Goal-related beliefs play a crucial role in guiding the actions of learners and help them self-regulate their behaviour in achievement contexts (Lent et al., 1994). The *achievement goal theory* (Ames & Archer, 1988; Dweck, 1986; Elliot & Harackiewicz, 1996) is an established framework to assess the interplay of goals in learning contexts with motivational processes as goal orientations. Different conceptualisations have prompted an ongoing discourse in the scientific literature on the composition and the factorial structure of achievement goals (e.g., Hulleman et al., 2010; Lüftenegger et al., 2019). The conceptualisation of Harackiewicz et al. (1997) distinguishes between *mastery goals*, *performance goals*, and *work avoidance goals*: Mastery goals are oriented towards progress in learning and mastery; they facilitate intrinsic motivation. Learners who are oriented towards performance approach goals strive to display competence. Both mastery and performance goals are related to perseverance in the face of challenges, a positive attitude toward learning, and a preference for challenging tasks. Learners with a strong performance avoidance goal orientation view achievement settings as a threat and exhibit anxiety and helpless reactions in the face of challenges.

The stage-environment fit theory offers a suitable theoretical framework for generating hypotheses on how these variables evolve during upper secondary education.

Stage-environment fit theory

Stage-environment fit theory (SEFT; Eccles et al., 1993) posits that it is crucial for the development of achievement motivation that there is a good fit between one's individual needs and the affordances of one's social environment. This premise has been used successfully to explain changes in achievement motivation during adolescence. A change of individual needs (e.g., need for more autonomy or self-focus) or the educational environment (e.g., a new circle of friends, waning parental involvement in school matters, more distant student-teacher relationships) can improve the fit between needs and affordances or lead to a mismatch (Scherrer & Preckel, 2018).

In a comprehensive review of scholarly works examining the dynamics of motivational variables throughout different developmental stages, several variables have been found to decrease during the school careers of adolescents (Scherrer & Preckel, 2018). Specifically, mastery and performance approach goals (see Section 'Social cognitive career theory') have been found to decline, while, by and large, no changes in performance avoidance goals and self-efficacy have been identified. SEFT explains the adverse psychological developments caused by increased student needs that are not fulfilled by the school environment.

While SCCT describes mechanisms in the development of career-related intentions and choices, SEFT makes statements and has prompted empirical evidence about the decline in motivational variables in adolescence and beyond. This shared focus of concepts makes both these theories highly relevant to our research aim and will guide our hypotheses and methodological considerations.

Research aims and hypotheses

In this work, we conduct a cross-sectional multi-cohort study among Austrian academic upper secondary school students (grades 9-13). We aim to identify differences by gender and age cohorts in students' intentions to enrol in a STEM field degree at university during upper secondary education. Based on SCCT, we investigate self-efficacy, instrumentality (operationalising outcome expectations), and achievement goals in the context of learning mathematics as indicators of STEM career intentions. Our research goals are to find out (RG1) how such intentions evolve across different age cohorts in upper secondary education; (RG2) potential gender effects in the evolution of intentions; (RG3) how self-efficacy, instrumentality, and goals related to learning mathematics differ between students with and without STEM field aspirations.

Regarding age differences in the course of upper secondary education (RG1), we expect, as proposed by SEFT, that self-efficacy (H1a) and outcome expectations (H1b) related to learning mathematics are lower for students in higher grades. Similarly, we hypothesise that among students in higher grades, mastery approach goals (H1c) and performance approach goals (H1d) related to learning mathematics are lower and that work avoidance goals (H1e) are more manifest.

Given the frequent observation that male students exhibit higher mathematics self-efficacy than female students (e.g., Arens et al., 2022; Pajares, 2005; Sahin et al., 2023) and that, generally, male students decide more frequently on a STEM track than female students (e.g., Sahin et al., 2023), we hypothesise regarding potential gender effects (RG2) that male students have higher self-efficacy (H2a), higher outcome expectations (H2b), higher mastery and performance goals (H2c, H2d), and lower work avoidance goals (H2e) related to learning mathematics than female students. In accordance with Nagy et al. (2010), we also hypothesise that the gender gaps remain stable as the students proceed to higher grades, specifically, that the difference between male and female students in self-efficacy (H3a), outcome expectations (H3b), and achievement goals (H3c, H3d, H3e) related to learning mathematics remains stable.

Recent studies related to SCCT (e.g., Sahin et al., 2023; van Aalderen-Smeets et al., 2019) have found higher mathematics self-efficacy for aspirants of STEM degrees. Therefore, and because of the hypothesised higher personal importance of mathematics for aspirants of STEM degrees, we hypothesise that aspirants of STEM degrees (RG3) exhibit higher mathematics self-efficacy (H4a). Similarly, we hypothesise that these students show higher outcome expectations (H4b), higher mastery and performance goals (H4c, H4d), and lower work avoidance goals (H4e) related to mathematics than those who do not aspire to a STEM degree.

Finally, we hypothesise that self-efficacy, outcome expectations, and goals are more clearly formed the closer students get to the decision of whether to enrol in a STEM field degree or not. Thus, we hypothesise that there is an interaction between grade and STEM intentions regarding self-efficacy (H5a), outcome expectations (H5b), and achievement goals (H5c, H5d, H5e).

An overview of the hypotheses is provided in Table 1.

Table 1. Hypotheses

Construct	**Grade**	**Gender**	**Grade * gender**	**STEM**	**Grade * STEM**
Self-efficacy	H1a (lower in higher grades)	H2a (male > female)	H3a (advantage for male students)	H4a (STEM > other)	H5a (bigger gap in higher grades)

Construct	Grade	Gender	Grade * gender	STEM	Grade * STEM
Outcome expectations	H1b (lower in higher grades)	H2b (male > female)	H3b (advantage for male students)	H4b (STEM > other)	H5b (bigger gap in higher grades)
Mastery approach goals	H1c (lower in higher grades)	H2c (male > female)	H3c (advantage for male students)	H4c (STEM > other)	H5c (bigger gap in higher grades)
Performance approach goals	H1d (lower in higher grades)	H2d (male > female)	H3d (advantage for male students)	H4d (STEM > other)	H5d (bigger gap in higher grades)
Work avoidance goals	H1e (higher in higher grades)	H2e (male < female)	H3e (advantage for male students)	H4e (STEM < other)	H5e (bigger gap in higher grades)

Methods

A questionnaire study in which all Austrian academic secondary schools were invited to participate was carried out to generate a representative sample of the population of upper secondary school students in Austria with regard to gender and the proportion of students in public and private schools. The participants were asked how firmly they intended to enrol in a university degree programme after graduation and, if any, which fields they considered. The questionnaire comprised items on several motivational and affective factors related to learning mathematics, the students' current performance in mathematics, and their educational and sociological background. In this study, we conduct a secondary analysis of the collected data using a selection of scales from the questionnaire related to the hypotheses outlined in Section 'Research aims and hypotheses'.

Study design

This study is a single-wave online questionnaire study conducted via the online survey software *Unipark*. In February 2023, all 362 academic secondary schools in Austria were contacted by email and asked to participate in the study with their students in grades 9 to 13. Prior to this, the Boards of Education of all federal states except Vienna had given their approval to conduct the study. In Vienna, the decision of whether to participate in scientific studies lies within the responsibility of each school. Schools were promised a book token worth 100 Euros if they would be among the first 50 schools with at least 50 participants. In addition, the Austrian Federal Ministry of Education, Science and Research placed an advert on their website leading directly to the questionnaire. Data were collected between February 15th and April 2nd, 2023. Participation was subject to informed consent of the participants.

Participants

In the school year 2022/23, 86,841 students[1] attended academic upper secondary schools[2] in Austria. During the data cleaning, the initial number of 6356 respondents (response rate: 7.3 %) was reduced to 5474, excluding students from schools other than academic secondary schools, students in grade 13 of a specific type of academic secondary schools with five years in the upper secondary cycle, and students who had responded to less than one third of the outcome variables. Missing data in the outcome variables (up to 0.8 % at the item level) was imputed using multiple imputation with five imputation cycles following the procedure of Rubin (1987). The five resulting datasets were aggregated by computing mean values of the imputed variables.

[1] Data retrieved from *STATcube*, the statistical database of Statistics Austria, selecting school students from the school types ‘AHS-Oberstufe’, ‘Oberstufenrealgymnasien’ as of October 1st, 2022.
[2] Academic upper secondary schools comprise *Classical Academic Secondary Schools* (*Gymnasien*) and *Upper Level Academic Secondary Schools emphasising Mathematics and Science* (*Oberstufenrealgymnasien*), see https://www.bildungssystem.at/en/school-upper-secondary/academic-secondary-school-upper-cycle (retrieved December 21, 2023)

The resulting sample comprised 5474 students (year of birth: range = 2002–2010, M = 2006.2, SD = 1.3) from 137 schools. Of these students, 60.1% identified as female, 35.9% as male, 1.4% as diverse, and 2.6% did not indicate gender. This aligns perfectly with the most recent available data of 59% female students in academic upper secondary schools, making our sample representative of the population of academic upper secondary school students. Following the urban-rural-typology of Statistics Austria[3], 74.9% of the participants attended a school in an *urban centre*, 10.9% attended a school in a *regional centre*, 3.1% attended a school in a *rural area near a centre*, and 10.3% attended a school in a *rural area*. 0.8% of the participants did not provide this information. 81.0% of the participants attended a public school, and 19.0% attended a private school, which corresponds well to the most recent available percentages[1] of 83.3% of the academic upper secondary school students attending a federal school and 16.7% attending a private school. The number of participants in each grade is distributed almost equally over the grades, ranging from 20.3% to 29.0% in grades 9 to 12.

Measures

The questionnaire scales used for data analysis in this study comprise a selection of items of *mastery goals* (number of items: k = 3, sample item: 'Understanding maths is important to me.', McDonald's ω = .72), *performance goals* (k = 3, 'It is most important for me to get a good grade in maths.', ω = .75), and *work avoidance goals* (k = 5, 'In maths, I want to have a small workload.', ω = .80) (Harackiewicz et al., 1997). Outcome expectations were measured using the scale *instrumentality* (k = 4, 'Maths will play an important role for me in the future.', ω = .89) of Rakoczy et al. (2013). Self-efficacy was measured using the scale *school-related self-efficacy* (k = 4, 'When I try, I can solve also the difficult maths problems.', ω =

[3] Categorisation criteria: https://www.statistik.at/fileadmin/pages/453/urbanRuralTypolgie.pdf

.81; Schwarzer & Jerusalem, 1999). Slight adaptations regarding the wording of the original items had been made to fit the specific context of this study. All these constructs were surveyed using a 6-point Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree).

The participants indicated their intention to enrol in tertiary education by responding to the item 'Can you imagine to study at university after graduation?' on a six-point Likert-type scale. Those who selected an answer other than 'not at all' were then asked to indicate which fields of study they would most likely enrol in. The responses to the fields of study were used to group students into STEM aspirants, i.e., students selecting STEM fields as a potential university degree, and others, i.e., students selecting fields other than STEM fields as a potential university degree, to allow for group comparisons in the analysis.

Data analysis

The data were analysed using *IBM SPSS Statistics 29* and *R 4.3.3*. To process the responses to the individual items, the mean of the items making up a scale was computed and used for the analysis. Bivariate correlations between the constructs related to the SCCT are summarised in Table 2. We used *t*-tests to test for differences between female and male students and between STEM aspirants and others. The significance values were corrected for multiple comparisons using the Bonferroni method. To test our hypotheses where multiple mean values are to be compared, we conducted univariate analyses of variance (ANOVA) using the SCCT variables as dependent variables and the grouping variables gender, grade, and STEM intention as independent variables. Moreover, we examined the interaction effects between grade and gender as well as between grade and STEM intention. In comparisons of gender, on account of low incidence, we chose not to include participants who stated their gender to be 'diverse' or did not declare their gender. In comparing student cohorts of different grades, we confined the data to students from grades 9 to 12 due to a low number of students from grade 13. For the interpretation of the results, we consider both the statistical significance of differences as well as η^2 as the effect size, where $\eta^2 = .01$ represents a small effect, $\eta^2 = .06$ a medium effect, and $\eta^2 = .14$ a large effect. For t-tests, we use Cohen's d as a measure for the effect size and consider the common thresholds of $|d| = 0.2$ a small effect, $|d| = 0.5$ a medium effect, and $|d| = 0.8$ a large effect (Cohen, 1988).

Table 2. Bivariate correlations (Pearson correlation coefficient)

	Construct	**1**	**2**	**3**	**4**	**5**	**M**	**SD**
1	Self-efficacy	-					3.78	1.26
2	Instrumentality	.44	-				3.37	1.35
3	Mastery approach goals	.43	.47	-			4.28	1.18
4	Performance approach goals	.22	.19	.40	-		4.62	1.15
5	Work avoidance goals	-.50	-.44	-.48	-.13		4.16	1.15
6	Grade (1 = highest, 5 = lowest)	-.55	-.30	-.26	-.30	.32	2.81	1.26

Note. n = 5474. All bivariate correlations are statistically significant ($p < .001$), M…mean, SD…standard deviation.

Results

Descriptive statistics can be found in Table 3. In this section, we report the results from t-tests (see Table 4) and ANOVA results (Table 5). The entire collection of figures visualising gender differences and the differences between students with and without stem aspirations can be found in the supplementary material.

Differences in SCCT variables between age cohorts

In the following, we contrast SCCT aspects of age cohorts with one another to obtain insights into the differences that appear in these aspects during upper secondary education. Figure 1 provides an overview of the differences seen in the SCCT variables by gender and age cohorts. In Table 4, we report pairwise differences in detail.

Table 3. Descriptive statistics

Construct	All grades			Grade 9			Grade 10			Grade 11			Grade 12		
	N	**M**	**SD**	**n**	**M**	**SD**	**n**	**M**	**SD**	**n**	**M**	**SD**	**n**	**M**	**SD**
Self-efficacy	5474	3.78	1.26	1517	3.72	1.20	1587	3.74	1.25	1261	3.78	1.31	1109	3.90	1.28
female	3289	3.57	1.25	890	3.56	1.22	982	3.58	1.25	739	3.52	1.28	678	3.62	1.25
male	1967	4.16	1.19	552	4.04	1.12	548	4.07	1.17	470	4.20	1.24	397	4.39	1.21
STEM	1491	4.47	1.13	369	4.34	1.10	426	4.44	1.14	373	4.52	1.15	323	4.61	1.10
no STEM	3801	3.53	1.20	1086	3.54	1.16	1110	3.49	1.17	847	3.48	1.24	758	3.62	1.24
Instrumentality	5474	3.37	1.35	1517	3.48	1.31	1587	3.38	1.34	1261	3.27	1.35	1109	3.30	1.39
female	3289	3.26	1.32	890	3.41	1.31	982	3.29	1.33	739	3.18	1.31	678	3.10	1.33
male	1967	3.57	1.36	552	3.64	1.30	548	3.58	1.35	470	3.44	1.38	397	3.64	1.41
STEM	1491	4.31	1.12	369	4.41	1.05	426	4.32	1.08	373	4.18	1.19	323	4.33	1.18
no STEM	3801	3.02	1.23	1086	3.18	1.23	1110	3.04	1.24	847	2.89	1.20	758	2.89	1.23
Mastery approach goals	5474	4.28	1.18	1517	4.43	1.14	1587	4.34	1.16	1261	4.18	1.21	1109	4.12	1.22
female	3289	4.29	1.17	890	4.48	1.14	982	4.39	1.16	739	4.18	1.19	678	4.05	1.18
male	1967	4.27	1.20	552	4.37	1.14	548	4.28	1.17	470	4.18	1.24	397	4.23	1.26
STEM	1491	4.80	1.02	369	4.86	1.00	426	4.83	0.99	373	4.75	1.04	323	4.74	1.06
no STEM	3801	4.10	1.17	1086	4.30	1.14	1110	4.17	1.16	847	3.95	1.18	758	3.89	1.18

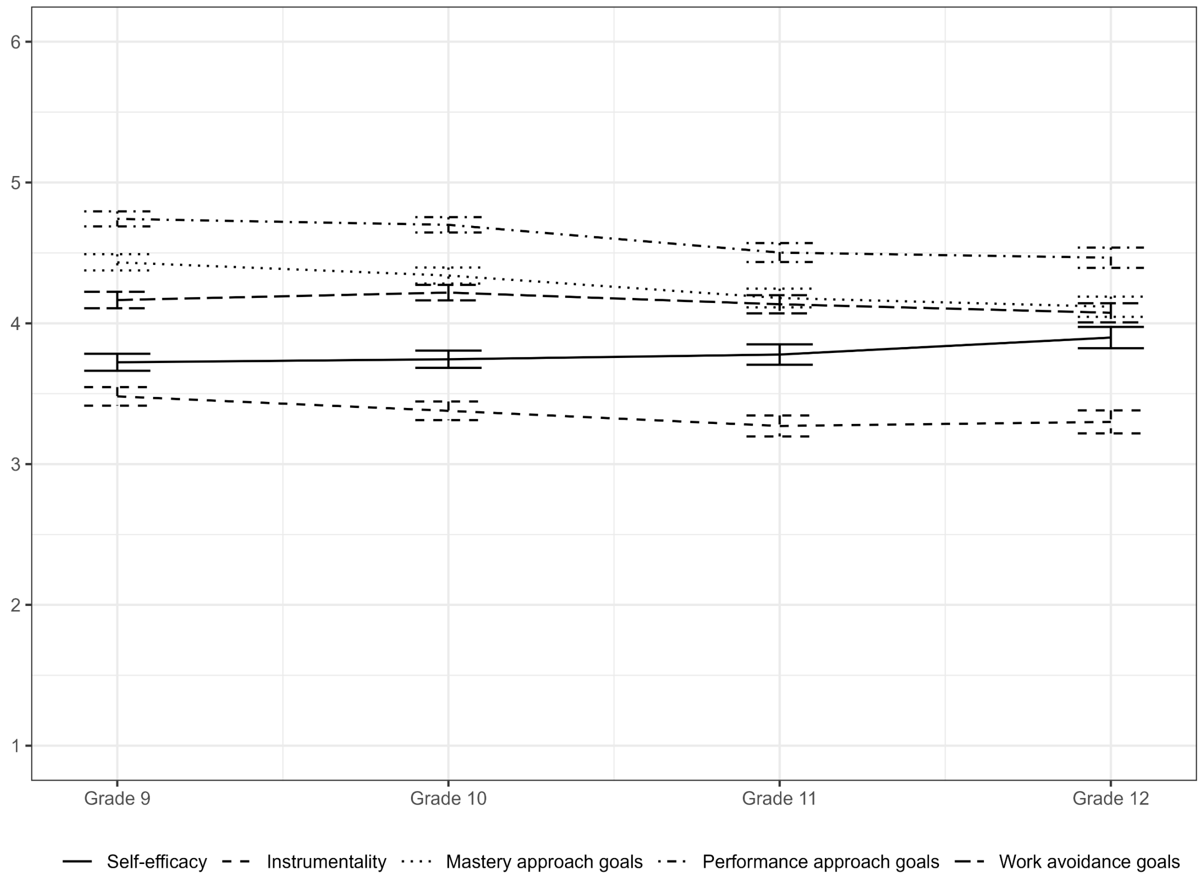
Construct	All grades			Grade 9			Grade 10			Grade 11			Grade 12		
	N	**M**	**SD**	**n**	**M**	**SD**	**n**	**M**	**SD**	**n**	**M**	**SD**	**n**	**M**	**SD**
Performance approach goals	5474	4.62	1.15	1517	4.74	1.06	1587	4.70	1.10	1261	4.50	1.22	1109	4.47	1.22
female	3289	4.75	1.06	890	4.85	1.00	982	4.82	1.02	739	4.69	1.12	678	4.60	1.12
male	1967	4.41	1.24	552	4.56	1.12	548	4.51	1.18	470	4.25	1.32	397	4.26	1.32
STEM	1491	4.74	1.13	369	4.79	1.11	426	4.87	1.06	373	4.66	1.19	323	4.61	1.18
no STEM	3801	4.59	1.14	1086	4.75	1.03	1110	4.65	1.09	847	4.45	1.22	758	4.42	1.23
Work avoidance goals	5474	4.16	1.15	1517	4.17	1.15	1587	4.22	1.12	1261	4.14	1.17	1109	4.07	1.15
female	3289	4.21	1.13	890	4.16	1.15	982	4.28	1.10	739	4.20	1.12	678	4.18	1.15
male	1967	4.04	1.17	552	4.13	1.17	548	4.09	1.16	470	4.02	1.22	397	3.89	1.12
STEM	1491	3.61	1.15	369	3.71	1.21	426	3.69	1.10	373	3.54	1.11	323	3.49	1.19
no STEM	3801	4.35	1.07	1086	4.30	1.10	1110	4.41	1.06	847	4.38	1.08	758	4.30	1.05

Note. n…sample size, M…mean, SD…standard deviation, 'STEM'…students with STEM career intentions, 'no STEM'…students without STEM career intentions

There are statistically significant differences in self-efficacy between different age cohorts. In contrast to the hypothesis (H1a), self-efficacy is higher in higher grades with a very small effect size. Post hoc tests reveal that self-efficacy in grade 12 is statistically significantly higher than in grade 9 or 10, both with small effect size.

Outcome expectations, as measured by the perceived instrumentality of mathematics (H1b), are statistically significantly different across grades 9 to 12, albeit with a very small effect size. Post hoc tests show that outcome expectations are statistically significantly lower in grade 11 than in grade 9 and lower in grade 12 than in grade 9, both with small effect size.

Figure 1. Comparison of SCCT aspects in grades 9 to 12



Mastery approach goals vary statistically significantly among students in different grades with a small effect size (H1c). According to post hoc tests, mastery approach goals are lower in grade 11 than in grade 9 or 10 and lower in grade 12 than in grade 9 or 10, all with small effect size.

The data show statistically significant differences in performance approach goals between students in different grades (H1d, small effect size). Pairwise comparisons show that students in grades 11 or 12 had statistically significantly lower performance goals than students in grades 9 or 10 (each pairwise comparison: $p < .001$, each with small effect size).

Work avoidance goals differ statistically significantly across grades 9 to 12 (H1e), albeit with a small effect size. Post hoc tests show that students' work avoidance goals are statistically significantly lower in grade 12 than in grade 10 with very small effect size; no statistically significant differences are seen in other pairwise comparisons.

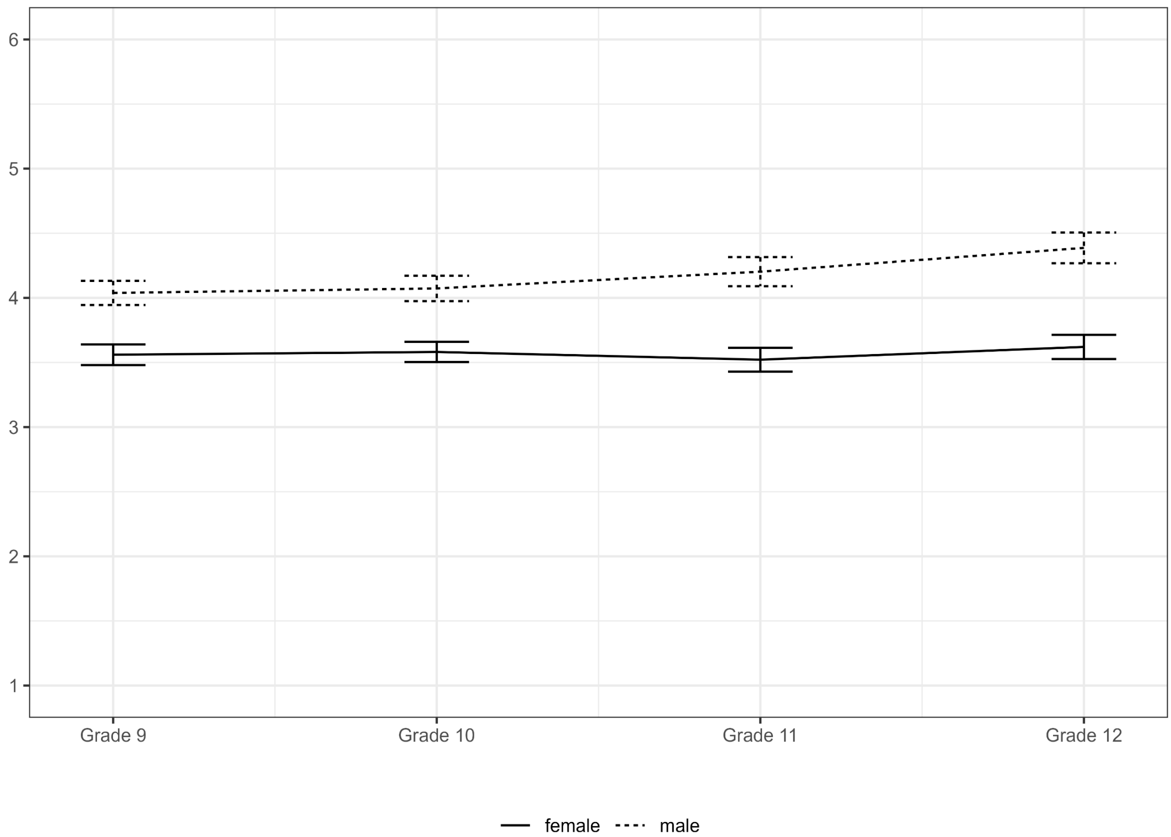
Gender differences in SCCT variables

Across the whole sample, male students exhibit higher mathematics self-efficacy (H2a, small to medium effect size) and higher instrumentality (H2b, small effect size) than female students (see Table 3). As for achievement goals, gender differences are not uniform: While there is no statistically significant difference in mastery goals (H2c), female students exhibit both higher performance goals (H2d, small effect size) and higher work avoidance goals (H2e, small effect size).

Also, the gender disparity in self-efficacy differs statistically significantly from one age cohort to another (H3a, see Table 5, column 'Grade * gender'; see Figure 2), albeit with a very small effect size. Pairwise comparisons of age cohorts show that, among female students, no statistically significant differences in self-efficacy between age cohorts can be found, while among male students, self-efficacy is higher in grade 12 than in grade 9 ($p < .001$; small effect size) or grade 10 ($p = .003$; small effect size).

There is a statistically significant interaction between grade and gender with regard to outcome expectations (H3b, small effect size). While there are no significant differences between male students in different grades, female students' outcome expectations are reported to be lower in grade 11 than in grade 9 (p = .021; small effect size) and lower in grade 12 than in grade 9 (p < .001; small effect size).

Figure 2. Differences in mathematics self-efficacy across grades 9 to 12 by gender



As for mastery goals, there is a statistically significant interaction between grade and gender of small effect size (H3c). While there are no significant differences between male students in different grades, they are lower among female students in grade 11 than grade 9 (p < .001; small effect size) or grade 10 (p = .005; small effect size) and lower in grade 12 than in grade 9 (p < .001; small to medium effect size) or 10 (p < .001; small effect size).

Table 4. Comparison of SCCT variables by grade

Construct	**All grades**				**Grade 9**				**Grade 10**				**Grade 11**				**Grade 12**			
	ΔM	**SE**	**p**	**d**	**ΔM**	**SE**	**p**	**d**	**ΔM**	**SE**	**p**	**d**	**ΔM**	**SE**	**p**	**d**	**ΔM**	**SE**	**p**	**d**
Self-efficacy																				
female vs. male	-0.587	0.035	<.001	0.48	-0.484	0.066	<.001	0.41	-0.494	0.065	<.001	0.40	-0.680	0.072	<.001	0.54	-0.741	0.077	<.001	0.62
STEM vs. no STEM	0.944	0.036	<.001	0.80	0.801	0.070	<.001	0.70	0.936	0.073	<.001	0.82	1.043	0.073	<.001	0.86	0.979	0.077	<.001	0.83
Instrumentality																				
female vs. male	-0.313	0.038	<.001	0.23	-0.236	0.072	.001	0.18	-0.284	0.071	<.001	0.22	-0.254	0.079	.001	0.19	-0.521	0.084	<.001	0.40
STEM vs. no STEM	1.290	0.037	<.001	1.08	1.199	0.072	<.001	1.04	1.271	0.068	<.001	1.07	1.307	0.074	<.001	1.08	1.437	0.079	<.001	1.18
Mastery approach goals																				
female vs. male	0.022	0.034	.523	0.02	0.096	0.063	0.128	0.10	0.114	0.062	0.068	0.09	-0.007	0.069	0.921	0.00	-0.191	0.074	.009	0.15
STEM vs. no STEM	0.695	0.035	<.001	0.61	0.550	0.067	<.001	0.51	0.659	0.064	<.001	0.59	0.808	0.070	<.001	0.70	0.846	0.074	<.001	0.74
Performance approach goals																				
female vs. male	0.340	0.032	<.001	0.30	0.291	0.061	<.001	0.28	0.310	0.060	<.001	0.29	0.431	0.066	<.001	0.37	0.359	0.071	<.001	0.28
STEM vs. no STEM	0.153	0.035	<.001	0.13	0.026	0.068	.705	0.04	0.222	0.064	<.001	0.20	0.198	0.070	.005	0.17	0.208	0.075	.005	0.16

Construct	All grades				Grade 9				Grade 10				Grade 11				Grade 12			
	ΔM	**SE**	**p**	**d**	**ΔM**	**SE**	**p**	**d**	**ΔM**	**SE**	**p**	**d**	**ΔM**	**SE**	**p**	**d**	**ΔM**	**SE**	**p**	**d**
Work avoidance goals																				
female vs. male	0.163	0.033	<.001	0.14	0.038	0.062	.539	0.03	0.190	0.061	.002	0.17	0.169	0.067	.012	0.16	0.282	0.072	<.001	0.25
STEM vs. no STEM	-0.733	0.034	<.001	0.67	-0.597	0.065	<.001	0.52	-0.707	0.062	<.001	0.67	-0.838	0.068	<.001	0.77	-0.805	0.072	<.001	0.74

Note. ΔM…difference of means, SE…standard error, p…p-value of statistical significance, d…effect size (Cohen's d), 'STEM'…students with STEM career intentions, 'no STEM'…students without STEM career intentions

The interaction of grade and gender (H3d) with performance approach goals is not statistically significant ($p = .420$). Pairwise comparisons support this result in terms of lower performance approach goals in grade 12 compared to grades 9 and 10 both for male and female students (all $p < .03$). For male students, performance approach goals are additionally lower in grade 11 than in grade 9 ($p < .001$) and lower in grade 11 than in grade 10 ($p = .007$). All effect sizes are small.

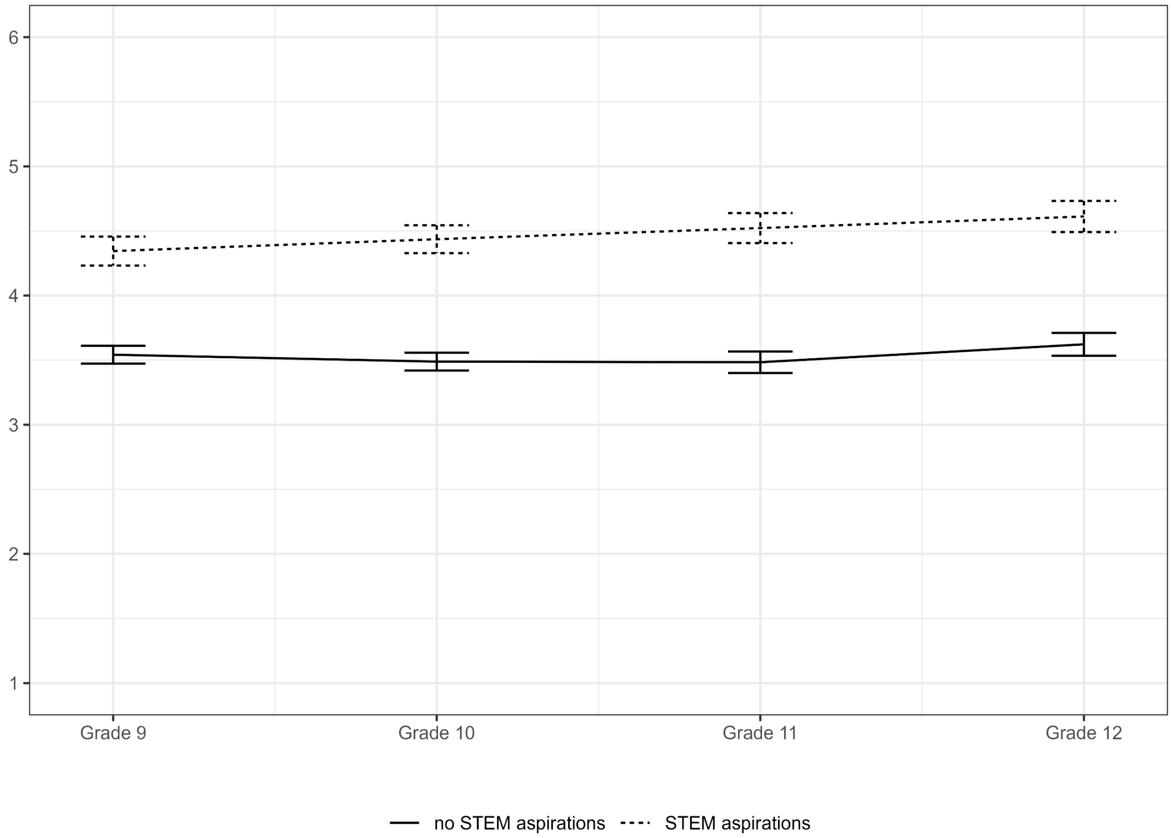
While the data exhibits no statistically significant interaction between grade and gender regarding work avoidance goals (H3e), pairwise comparisons suggest that work avoidance goals among male students are statistically significantly lower in grade 12 than in grade 9 ($p = .045$; small effect size). By contrast, female students show no statistically significant differences across grades.

Differences in SCCT variables between STEM degree aspirants and others

Comparing STEM degree aspirants to those who aspire to a degree other than STEM, the former exhibit higher mathematics self-efficacy (H4a, medium to strong effect size), higher instrumentality (H4b, strong effect size), higher mastery goals (H4c, medium effect size), higher performance goals (H4d, small effect size), and lower work avoidance goals (H4e, medium effect size).

The difference in self-efficacy between students aspiring to enrol in a STEM degree and those planning to enrol in a different degree programme (H5a, see Table 5, column ‘Grade * STEM’; see Figure 3) was stable across grades 9 to 12. However, pairwise comparisons suggest that self-efficacy is statistically significantly higher among STEM degree aspirants in grade 12 than in grade 9. At the same time, there are no statistically significant differences among those who plan to pursue a different degree.

Figure 3. Differences in mathematics self-efficacy across grades 9 to 12 between students aspiring to a STEM university degree and students aspiring to a university degree other than a STEM degree



The interaction between grade and STEM degree intentions with outcome expectations (H5b) is not statistically significantly different, even though among those who aspire to a degree other than STEM, there are differences between students in different grades with a small effect size ($F = 13.93$, $df = 3$, $df_R = 5362$, $p < .001$, $\eta^2 = .008$). Pairwise comparisons show that outcome expectations of those who do not aspire to a STEM degree are statistically significantly lower in grade 10 than in grade 9, lower in grade 11 than in grade 9, and lower in grade 12 than in grade 9, as well as lower in grade 11 than in grade 10.

Table 5. Results from analysis of variance (ANOVA)

Construct	**Gender**					**STEM**					**Grade**					**Grade * gender**					**Grade * STEM**				
	F	**df**	**df_R**	**p**	**η^2**	**F**	**df**	**df_R**	**p**	**η^2**	**F**	**df**	**df_R**	**p**	**η^2**	**F**	**df**	**df_R**	**p**	**η^2**	**F**	**df**	**df_R**	**p**	**η^2**
Self-efficacy	**282.50**	**1**	**5254**	**<.001**	**.051**	**686.36**	**1**	**5290**	**<.001**	**.115**	**4.73**	**3**	**5470**	**.003**	**.003**	**3.97**	**3**	**5248**	**.008**	**.002**	2.00	3	5284	.112	.001
Instrumentality	**67.72**	**1**	**5254**	**<.001**	**.013**	**1229.52**	**1**	**5290**	**<.001**	**.189**	**6.73**	**3**	**5470**	**<.001**	**.004**	**3.03**	**3**	**5248**	**.028**	**.002**	1.40	3	5284	.241	.001
Mastery approach goals	0.41	1	5254	.523	.000	**403.63**	**1**	**5290**	**<.001**	**.071**	**19.88**	**3**	**5470**	**<.001**	**.011**	**3.96**	**3**	**5248**	**.008**	**.002**	**3.77**	**3**	**5284**	**.010**	**.002**
Performance approach goals	**110.90**	**1**	**5254**	**<.001**	**.021**	**19.32**	**1**	**5290**	**<.001**	**.004**	**19.37**	**3**	**5470**	**<.001**	**.011**	0.92	3	5248	.430	.001	1.58	3	5284	.191	.001
Work avoidance goals	**24.95**	**1**	**5254**	**<.001**	**.005**	**479.63**	**1**	**5290**	**<.001**	**.083**	**3.58**	**3**	**5470**	**.013**	**.002**	**2.64**	**3**	**5248**	**.048**	**.002**	**2.70**	**3**	**5284**	**.044**	**.002**

Note. Figures set in bold are statistically significant at the 0.05 level.

The interaction between grade and STEM intentions with regard to mastery approach goals (H5c) is statistically significant with a very small effect size. Among those who do not aspire to a STEM degree, mastery approach goals are lower in grade 10 than in grade 9, lower in grade 11 than in grade 9 or 10, and lower in grade 12 than in grade 9 or 10.

The interaction of grade and STEM intentions (H5d) with performance approach goals is not statistically significant ($p = .133$).

There are statistically significant differences in work avoidance goals between students with STEM intentions and those without (H5e), though with a small effect size. Pairwise comparisons show that work avoidance goals are statistically significantly lower in grade 12 than grade 9 or 10 among those who aspire to a STEM degree.

In addition, we note that the grades on the most recent mathematics exam (1 = highest, 5 = lowest) of STEM aspirants ($M = 2.51$, $SD = 1.32$) were better than those of students with no intention of enrolling in a STEM field degree ($M = 3.21$, $SD = 1.30$); this difference is statistically significant ($t = 17.39$, $df = 5264$, $p < .001$) with medium effect size ($d = 0.53$).

Discussion

This study aimed to identify the manifestation of motivational aspects related to learning mathematics that are crucial when adolescents contemplate and decide to pursue a STEM degree in tertiary education. According to SCCT, the most crucial motivational predictors of university aspirations are self-efficacy, outcome expectations, and goals.

In our study, we examined differences in self-efficacy, outcome expectations (operationalised by perceived instrumentality of mathematics), and achievement goals between students in different grades, between genders, and between students with STEM intentions and those without. We included the most recent mathematics exam grade as a control variable. Finally, we investigated potential interaction effects between grade level and gender and between grade level and STEM intentions.

Limitations

Before discussing the results obtained in this work, we outline the limitations that should be observed when interpreting the results. First, the participants of our study were students from academic secondary schools that aim to prepare adolescents for tertiary education, usually with a focus on general education. This results in a relatively homogenous population, in which any differences that may occur in the observed variables can be expected to be small. This study did not cover students from colleges who were pursuing higher vocational education that focused on specialist education. Second, our study did not differentiate between specific disciplines within STEM. Since gender differences are more present in some STEM fields than in others, our study might not reveal whether the disparities apply only or mostly to specific STEM fields. Future research should be framed in a way that enables this distinction. Third, our study did not measure developments with several measurement points; instead, we identified differences between these age cohorts in cross-sectionally collected data. Since the number of students in each age cohort (except for grade 13) is large (n > 1100) and because these numbers are of comparable size, we expect that the data still reflect reliable indicators of how the SCCT aspects vary throughout upper secondary education. Extending this study to a trend study by repeating the data collection to several measurement points would increase the reliability of the results.

Fourth, the students reported their intention to enrol in a STEM degree during upper secondary school. These reported intentions only serve as a proxy for future enrolment in tertiary education.

Differences between age cohorts

The manifestations of the SCCT variables explored in this study are mostly less favourable the higher the grade. This applies to outcome expectations, mastery approach goals, and performance approach goals. These results support the assumption that, everything considered, the mismatch between the affordances of the school environment of learners and the needs of learners increases with age. Surprisingly, mathematics self-efficacy was found to be higher in higher grades, particularly in grade 12. Note that this trend goes against the predictions of SEFT. Indeed, the scientific literature features many studies that identify stable or favourable trends in self-efficacy; however, overall, no consistent trend has emerged in meta-analyses (Scherrer & Preckel, 2018), possibly due to various operationalisations and measures for self-efficacy. A potential explanation for the higher self-efficacy in higher grades seen in our data is that the confidence of students to master mathematics tasks is boosted towards the end of upper secondary school when classes focus on practice for the centralised school leaving exams rather than new material.

Gender differences

The results of the study replicate findings of previous research on gender differences in mathematics self-efficacy. Moreover, we see how these differences align with outcome expectations and achievement goals related to learning mathematics. Specifically, this study confirms the results of prior studies (Arens et al., 2022; Pajares, 2005; Sahin et al., 2023) that male students exhibit higher mathematics self-efficacy than female students. In addition, our study shows that male students have higher outcome expectations of mathematics than female students do. As for achievement goals, other than hypothesised, female students have higher performance approach goals than male students. This suggests that, in comparison to male students, female students draw their motivation to learn mathematics more from prospective rewards or recognition by others rather than an intrinsic interest in the subject. This is consistent with results of Simon et al. (2015) which suggest that performance goals play a more important role for female than male students. Our data indicate that male students demonstrate lower work avoidance goals than female students, highlighting their advantageous position when selecting a STEM track. Thus, in conclusion, we are able to provide a more thorough picture of the motivational variables relevant to STEM intentions than prior studies could. In particular, we show that not only male students feel more confident that they will succeed in mathematics, but also that they see more benefit in learning mathematics in the first place. The scientific literature attributes such gender disparities mainly to internalised stereotypes in STEM contexts; these have been found to predict STEM self-efficacy, STEM outcome expectations, and STEM career interest (Luo et al., 2021).

When looking at how gender differences vary between age cohorts, our data show a tendency for gender differences to be larger in higher grades in all SCCT variables. With regard to self-efficacy, our study delivers results comparable to those of Nagy et al. (2010), showing that the trend throughout upper secondary education reinforces the favourable position of male students.

Previous studies have found that internalised stereotypes are reinforced during late adolescence (Martiny & Froehlich, 2020; Starr et al., 2021), which would explain the higher gender differences seen in students in higher grades in our study. Despite the small effect sizes, these differences are statistically significant and consistently in favour of male students. It suggests that gender biases regarding STEM are the more present, the closer students are to making decisions about studying at university.

Differences between STEM aspirants and their peers

STEM aspirants reported distinctly more favourable results in all five SCCT variables than their peers who aspire to a degree other than STEM. This confirms that the SCCT variables are indicative of STEM intentions. The results also show that these variables indicate STEM intentions not only when students are close to graduation but already at the beginning of upper secondary education, i.e., in grade 9. The observation that students have formed clear STEM intentions already at that stage is consistent with the finding of van Tuijl and Walma van der Molen (2016) that children and adolescents develop attitudes towards specific fields of work already at an early age and that their experiences before the age of 14 shape their own aspirations.

The data show larger differences in the SCCT variables the closer students are to graduation, suggesting that STEM intentions manifest in these variables very clearly in grades 11 and 12.

Conclusions

The results of this study offer new insights into several major factors that impact the development of intentions to pursue a STEM degree among upper secondary school students. Our main finding is that, overall, students have more confidence in their ability to master mathematical problems as they get closer to graduation. Students' conviction that they might benefit from their mathematical competencies later on in their lives decreases in the course of upper secondary education. Likewise, their goals to master mathematics drop. Investigating these differences gender by gender, however, reveals that higher confidence to master mathematics in higher grades is only present among male students. Moreover, only female students become less convinced that mathematical competencies will be relevant for them later on. As for goals, the intention to master mathematics is higher among female students at the beginning of upper secondary education than among male students and lower by the time of graduation. Work avoidance goals decrease only among male students.

Since all these differences are in favour of male students, we conclude that our study identifies specific detrimental consequences of prevalent gender stereotypes on female students with regard to STEM. Bandura (1995) recommended to strengthen efficacy by providing opportunities for mastery experiences or by creating venues where students can meet female STEM role models. Considering these recommendations, our results provide a strong incentive for society to push back against these stereotypes and advise parents, teachers, mentors, and educational advisors to portray female pioneers of STEM fields and to invite women in STEM careers to engage with their students. In this way, educational stakeholders have a leading role in reducing stereotypes and can pave the way into STEM careers with adequate interventions.

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Declaration of interests

The authors report there are no competing interests to declare.

Data availability

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Compliance with ethical standards

This study did not require ethics approval since the collected data did not include personal identifiers and were fully anonymous. Additionally, the study did not involve any interventions or interactions with the participants beyond the scope of their normal educational experiences. The Boards of Education of all federal states except Vienna and the school administrations of all schools in Vienna participating in this study had given their approval to conduct the study in advance. Participation in the study was voluntary and subject to informed consent.

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Supplementary material

This is supplementary material to

Mayerhofer M., Weinhandl R., Lüftenegger, M., & Eichmair, M.

Differences in STEM career intentions by gender and age cohorts during upper secondary education.

In the following, we provide plots for the gender differences and the differences between students with and without STEM aspirations.

Gender comparisons

Figure 1. Comparison of mathematics self-efficacy across grades 9 to 12 by gender

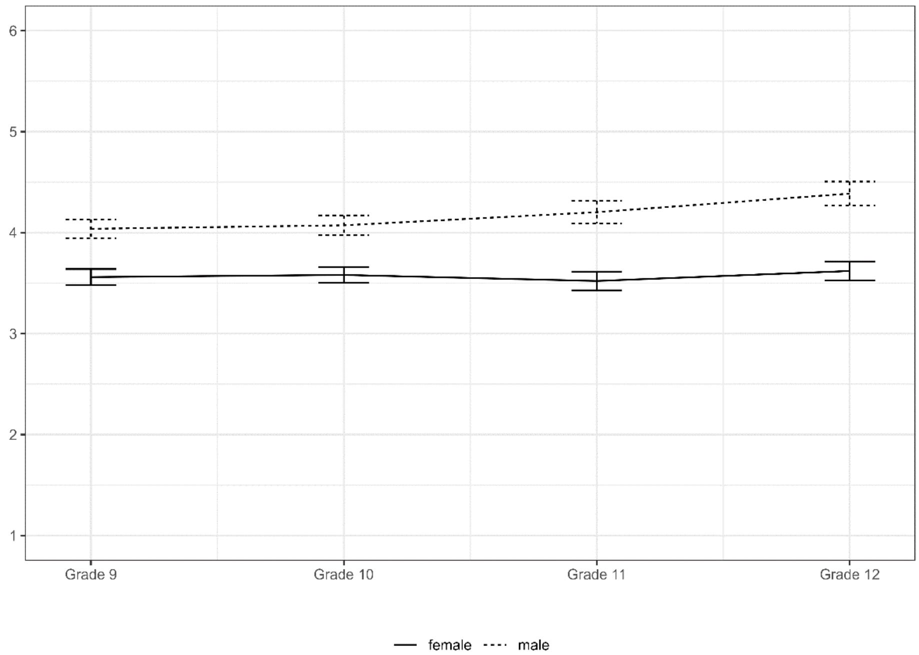


Figure 2. Comparison of perceived instrumentality of mathematics across grades 9 to 12 by gender

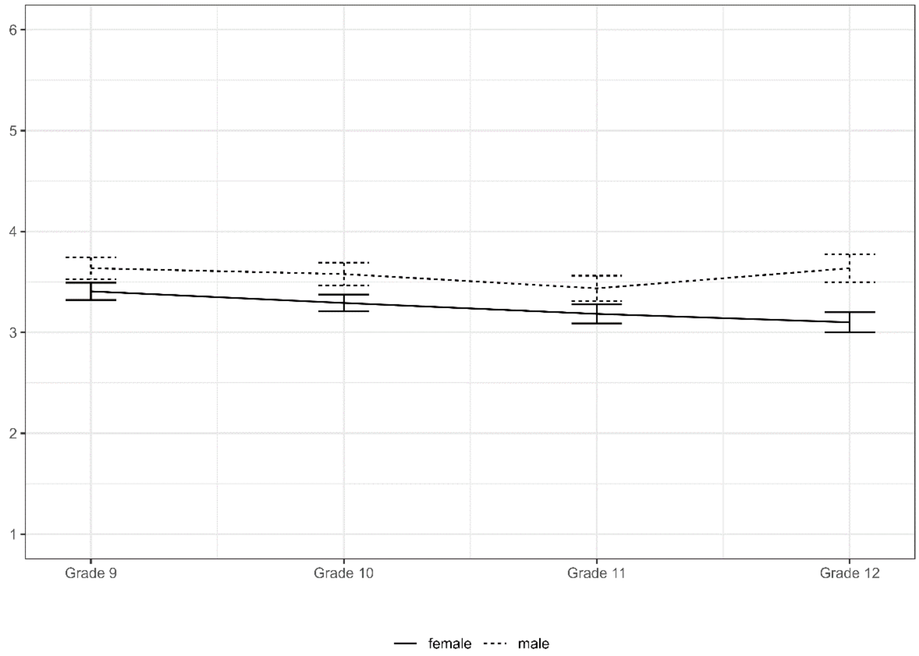


Figure 3. Comparison of mastery approach goals across grades 9 to 12 by gender

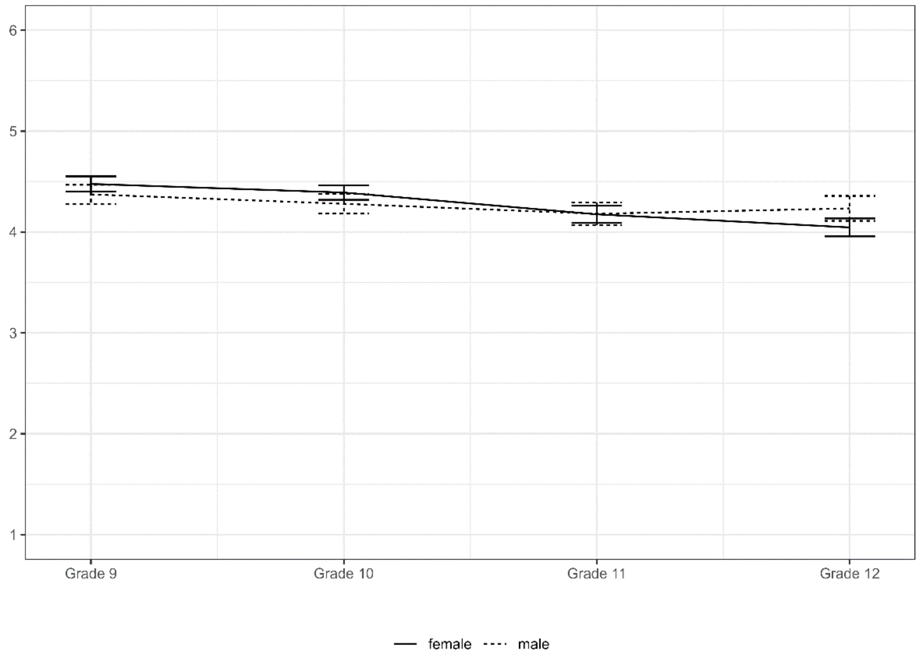


Figure 4. Comparison of performance approach goals across grades 9 to 12 by gender

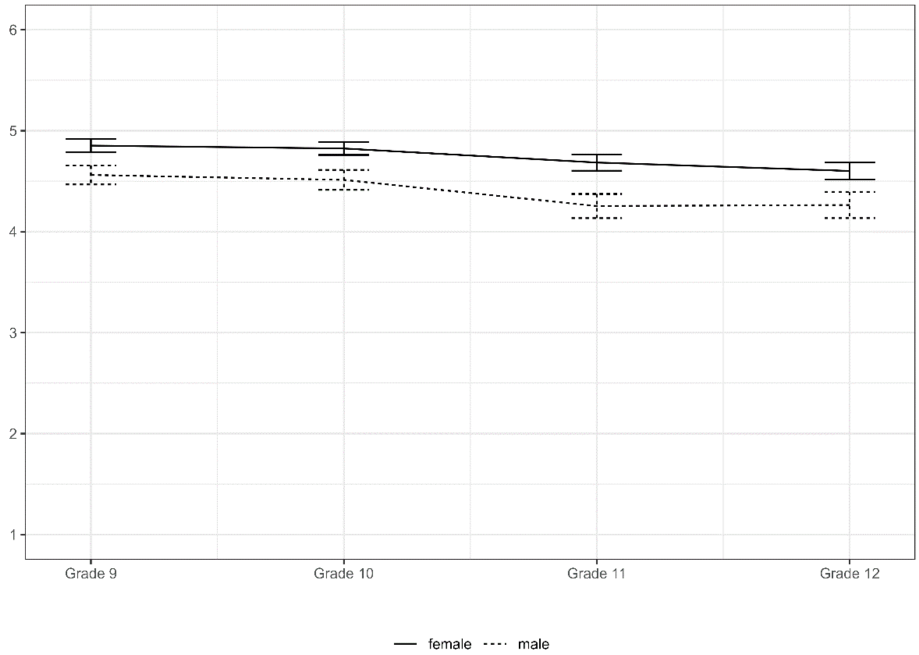
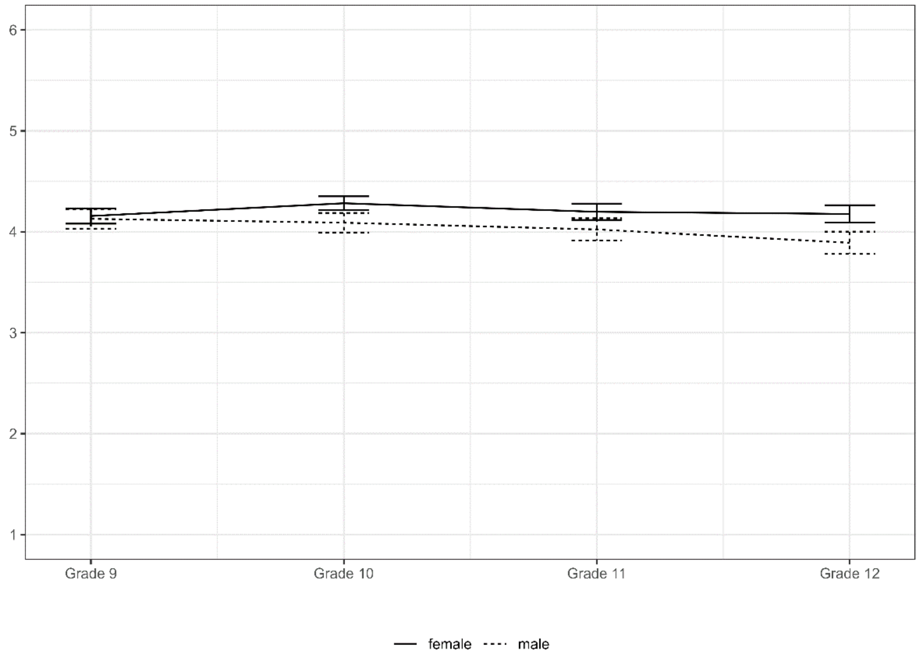


Figure 5. Comparison of work avoidance goals across grades 9 to 12 by gender



Comparisons of STEM aspirants and their peers

Figure 6. Comparison of mathematics self-efficacy across grades 9 to 12 among students aspiring to a STEM university degree and students aspiring to a university degree other than a STEM degree

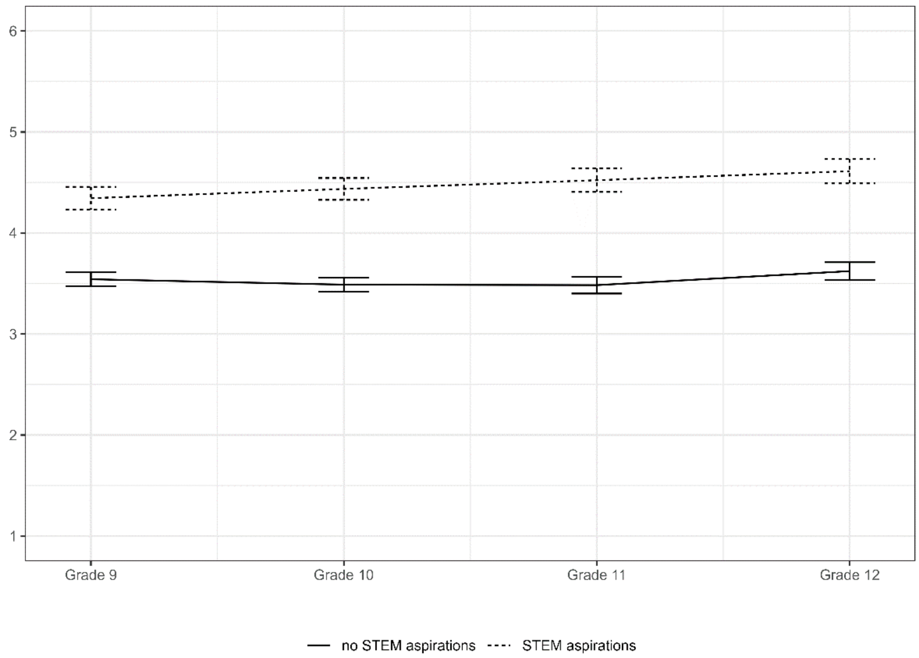


Figure 7. Comparison of perceived instrumentality of mathematics across grades 9 to 12 among students aspiring to a STEM university degree and students aspiring to a university degree other than a STEM degree

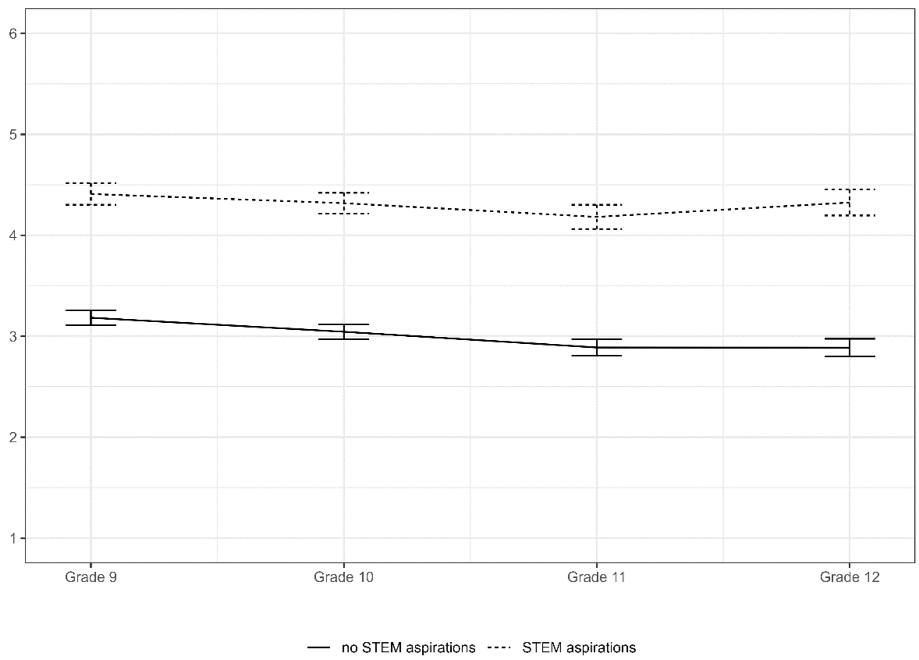


Figure 8. Comparison of mastery approach goals across grades 9 to 12 among students aspiring to a STEM university degree and students aspiring to a university degree other than a STEM degree

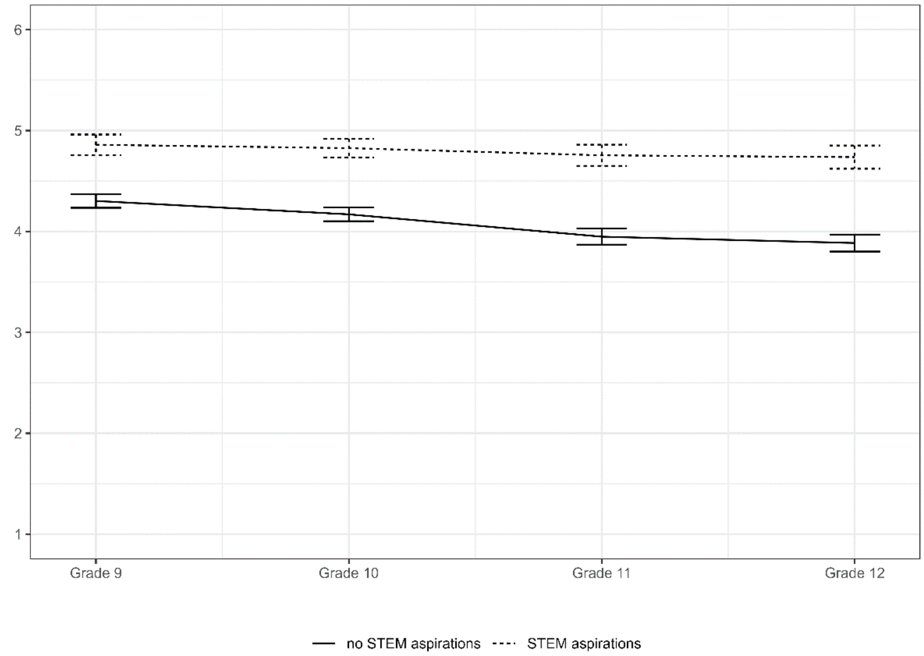


Figure 9. Comparison of performance approach goals across grades 9 to 12 among students aspiring to a STEM university degree and students aspiring to a university degree other than a STEM degree

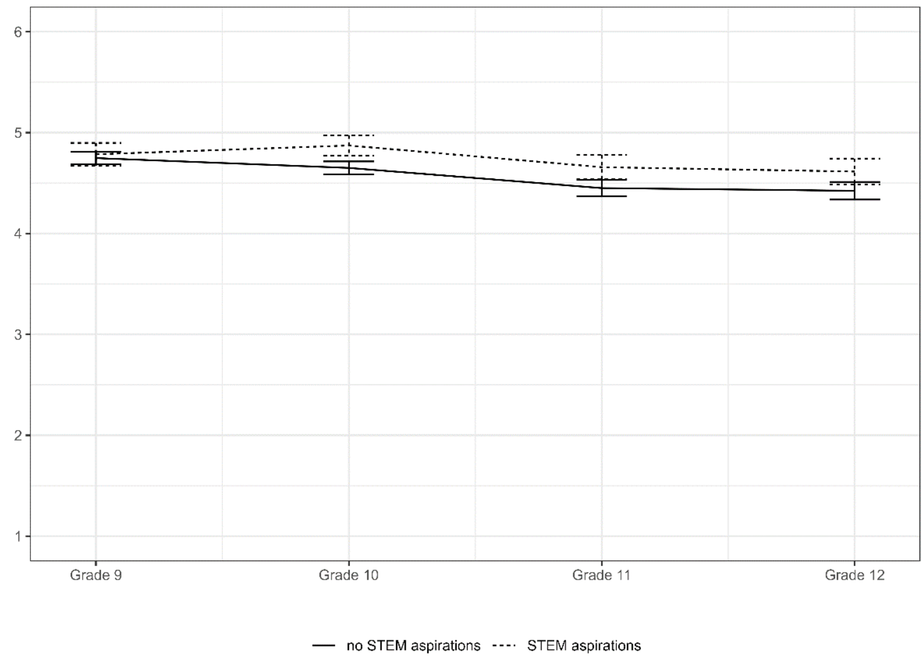
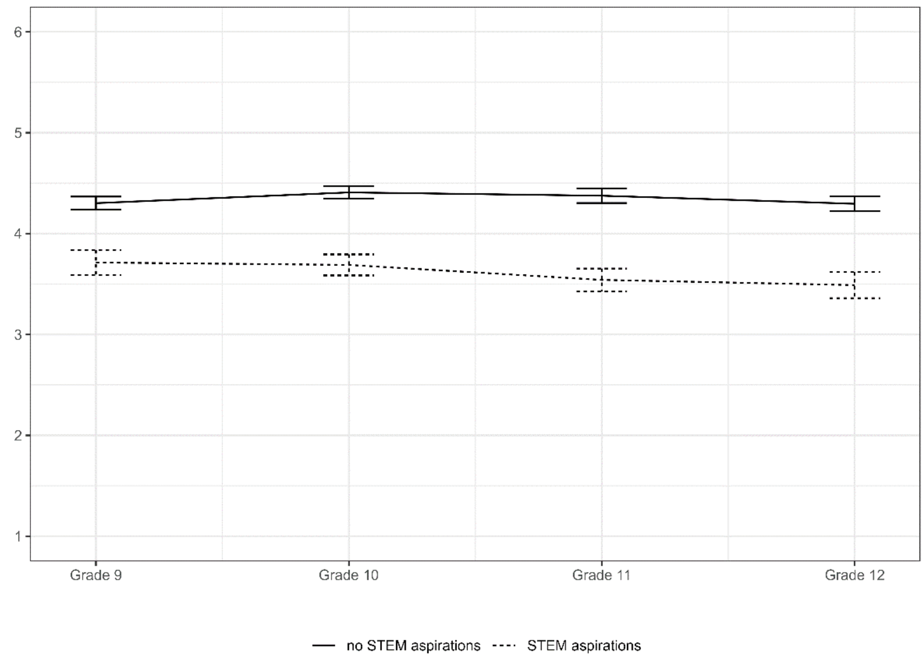


Figure 10. Trends in work avoidance goals across grades 9 to 12 among students aspiring to a STEM university degree and students aspiring to a university degree other than a STEM degree



6

Research article 2: Trends in expectancy for success and value beliefs at the secondary-tertiary transition into STEM fields

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Supervision: Michael Eichmair, Marko Lüftenegger

This article examines trends of motivational aspects related to learning mathematics among students in the course of their transition into STEM bachelor programs (RG2). By enrolling in such programs, students show a strong commitment to studying mathematics on a higher-than-school level. Now, dropout rates in STEM fields are among the highest among all degree programs (Heublein et al., 2022; Statistics Austria, 2022), suggesting that the initially high motivation of many students declines within a short period of time. In addition, there are significantly more men who enroll in STEM bachelor programs than women. Therefore, we also investigated whether beliefs related to learning mathematics developed differently for male and for female students in the course of their transition into university.

A repeated-measures study was set up to observe changes in motivation from the first day of a mathematics bridging course offered just before the beginning of the academic year until roughly two months into the first semester of various STEM bachelor programs at the Vienna University of Technology (TU Wien). While not mandatory, participation in the bridging course was strongly recommended by the university. Motivation was conceptualized by constructs specified in *expectancy-value theory* (Eccles, 1983). The theory distinguishes between *expectancy beliefs* that capture the self-perceived ability of learners to successfully complete a task and *value beliefs* that capture learners' rationales for engaging in a task. Expectancy beliefs are closely tied to intrinsic motivation. Value beliefs are divided into aspects tied to intrinsic motivation (*attainment value*, *intrinsic value*) and aspects tied to extrinsic motivation (*utility value*, *cost*). The validated scales of Gaspard et al. (2021) were used as a basis for the questionnaire of our study. The final questionnaire comprised items of nine scales representing both expectancy and value aspects. 428 students completed the questionnaires at both measurement points.

Repeated-measures analysis of variance was employed to test the changes between the two measurement points for statistical significance. The results show statistically significant maladaptive changes between the measurement points with medium to large effect size in all expectancy-value aspects. The results further indicate statistically significant gender differences in five out of nine constructs with a small effect size. All observed gender differences are in favor of male students.

The results suggest a general downward trend in achievement motivation among incoming students during the first few weeks at university, despite the high motivation of these students upon entering their respective programs. A possible explanation for this trend is the *big-fish-little-pond effect* (Marsh, 1987): Students who used to be among the best performers in mathematics at their respective schools are exposed to a new reference group where many have higher mathematical competence than their former academic peers. Our results show that the gender differences in achievement motivation in favor of male students already seen in secondary education continue to manifest themselves during the secondary-tertiary transition. While this study gives a broad picture of the development of motivation during this transition, the analysis of subgroups in research article 3 identifies the students who are particularly affected by challenges of the secondary-tertiary transition.

Trends in expectancy for success and value beliefs at the secondary-tertiary transition into STEM fields

Martin Mayerhofer, Michael Eichmair, Marko Lüftenegger

Trends in expectancy for success and value beliefs at the secondary-tertiary transition into STEM fields

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The elevated dropout rates in degree programs in science, technology, engineering, and mathematics (STEM) are in apparent contrast to the high mathematical self-concept prevalent among incoming students in these fields. This suggests that the attitudes and beliefs of students in STEM fields are challenged at the secondary-tertiary transition. This study expands research on expectancy and value beliefs in the context of schools to higher education. A longitudinal questionnaire study was conducted among beginning students in STEM fields (N = 428) to examine the development of their expectancy for success and value beliefs related to mathematics in the course of the first two months at university. A consistent decrease is observed in all measured aspects of expectancy and value beliefs. Significant differences depending on gender are seen in the developments of expectancy for success and several value beliefs, all in favour of male students.

Keywords: Expectancy-value theory, gender differences, secondary-tertiary transition, undergraduate students.

Introduction

Many studies have observed a steady decrease in the motivation to learn mathematics in the course of children's and adolescents' schooling (e. g., Lazarides et al., 2022; Schweder & Raufelder, 2022). Contrary to this overall trend, students who enter undergraduate programs in STEM fields (science, technology, engineering, mathematics) typically hold a high mathematics self-concept when graduating upper secondary school (Di Martino et al., 2022). Yet, bachelor programs in STEM fields have some of the highest dropout rates among all fields of study in Austria (56% between 2010 and 2020; Statistics Austria, 2022) and Germany (50% between 2016 and 2020; Heublein et al., 2022). Large-scale observations of gender differences in self-concept and attitudes in favour of male school students (e. g., Goldman & Penner, 2016) add a further dimension to this discrepancy between high mathematics self-concept and dropout. This calls for a closer scientific investigation of motivational beliefs of students and gender differences at the secondary-tertiary transition into STEM fields.

Challenges for beginning bachelor-level students on a formal, mathematical level have been studied extensively (e. g., Gueudet, 2008; Thomas et al., 2015). Less is known about what effects these challenges bear on students' motivational beliefs and about suitable ways of supporting students so their beliefs develop favourably. Di Martino et al. (2022) concluded from a qualitative transnational study that a high mathematical self-concept in secondary school is not necessarily maintained at university. Moreover, they found that a high mathematical self-concept at the end of upper secondary school is characteristic of students who enrol in STEM field programs, while a low mathematical self-concept at university fuels students' dropout intention. The mathematical self-concept of students thus plays a decisive role both for their intention to enrol in and decision to remain in an undergraduate STEM field program. In the context of both primary and secondary education, Wigfield and Eccles (2000) summarize the findings of several of their studies, showing that motivational beliefs have a significant impact on the choices made by students and – ultimately – on their performance, effort, and persistence as well. They based their investigations on the *expectancy-value theory* of achievement motivation (Eccles et al., 1983). Much research in education has been based on this theory. For example, Lazarides et al. (2022) created motivational profiles of grade 9 students and found a general decrease in motivation by the time they reached grade 10. Schweder and Raufelder (2022) observed positive effects of self-directed learning in grade 6 to grade 9 classrooms. Notably, gender differences in favour of male students were revealed, extending findings in the context of primary schools (e. g., Oppermann et al., 2021) and upper secondary schools (e. g., Watt et al., 2019). Gender differences in various expectancy beliefs have been observed among school students of all ages (Pajares, 2004). Giberti (2019) pointed to gender differences in task-specific mathematical self-efficacy and general mathematical self-concept detected by transnational surveys at the primary and secondary school level; these differences were reduced when controlled for school grades.

In the review of Huang (2013), gender differences in mathematics self-efficacy were found to be higher at college level than at any prior educational stage. The scientific literature is lacking studies on how student motivation develops during the secondary-tertiary transition and whether changes in motivation are gender-specific. Therefore, in this work, we pose the following research question:

> What gender differences, if any, are there in the development of students' achievement motivation as measured by expectancy-value theory during the secondary-tertiary transition into STEM fields?

We report general developments and point out differences with regard to gender where they arise.

Theory

Eccles et al. (1983) have established the *expectancy-value theory* of achievement motivation, asserting its close relation to how tasks are chosen and to what degree of persistence and ultimately success tasks are pursued. This theory incorporates beliefs in both its two dimensions *expectancy for success* (*expectancy beliefs*) and *task values* (*value beliefs*). Expectancy for success is the students' "perceived ability to succeed on a task", task values are the "reasons [of students] for engaging in a task" (Gaspard et al., 2015). Eccles et al. (1983) have further divided value beliefs into *attainment value* ("importance of doing well on a given task"), *intrinsic value* ("enjoyment one gains from doing the task"), *utility value* ("how a task fits into an individual's future plans"), and *cost* ("how the decision to engage in one activity […] limits access to other activities"). While utility value is related to extrinsic motivation, attainment value and intrinsic value are associated with intrinsic motivation (Gaspard et al., 2015). In line with, for example, Lazarides et al. (2022), we examine expectancy beliefs in terms of self-efficacy.

Based on the observation that students tend to have a high mathematics self-concept when entering university (Di Martino et al., 2022), on the one hand, and on the high dropout rates in STEM fields, on the other hand, we hypothesize that both expectancy beliefs and value beliefs of beginning students decrease in the course of the initial stage of their degree programs. We also hypothesize that the developments are in favour of male students when compared to female students.

Methods

We established a repeated-measures questionnaire study capturing expectancy and value beliefs of beginning students of the Vienna University of Technology, Austria, in the winter term 2022/23. Based on the well-established scales of Gaspard et al. (2021), we developed a questionnaire consisting of the subscales *general utility* and *utility for job* to measure utility value, the subscale *intrinsic value* to measure intrinsic value, the subscales *importance of achievement* and *personal importance* to measure attainment value, and the subscales *effort required*, *emotional cost*, and *opportunity cost* to measure cost (see Table 1). To measure expectancy values, a reduced version (three out of four original items) of the subscale *self-efficacy* was used. The selection of scales was based on the consideration that, out of the 16 scales of the original questionnaire of Gaspard et al. (2021), these were the relevant scales for the specific context of our study which had proven highly reliable in a small-scale pilot study (N = 35). We used a 6-point Likert scale (1 = "do not agree", 6 = "strongly agree") for collecting the data. A list with all items used is provided as supplementary material (available at https://phaidra.univie.ac.at/o:1771793).

Table 1: Sample items and internal consistencies of questionnaire scales

Construct	Sample item	Number of items	McDonald's ω	
			MP1	MP2
General utility	Math is very useful for me.	2	.653[a]	.705[a]
Utility for job	Math skills will pay off in my job later.	3	.900	.947
Intrinsic value	Math is fun.	3	.923	.931
Importance of achievement	Good grades in math are very important for me.	3	.866	.898
Personal importance	Math is important to me personally.	3	.849	.891
Effort required	Doing math is exhausting for me.	3	.851	.872
Emotional cost	Math is a real burden on me.	3	.737	.790
Opportunity cost	I have to give up many things to be good at math.	3	.827	.862
Self-efficacy	I am convinced that I can understand even the most difficult content in my degree program.	3	.858	.895

Note. n_{MP1}=428, n_{MP2}=402.

[a] For assessing the reliability of the two-item scale, the Spearman-Brown coefficient was calculated instead of McDonald's ω.

The questionnaire was administered to the students at the beginning of the mathematics bridging course in September 2022 (measurement point 1 = MP1) and about two months into the semester in November 2022 (MP2). We considered the bridging course a suitable opportunity to ask incoming students to participate in MP1 since the great majority of the beginning students at that university attend this course. The students were given time to fill in the questionnaire on site. This way, we aimed to reach a broad sample. The administration of the questionnaire before the start of classes should have helped ensure that answers given at MP1 capture experiences at school. For most incoming bachelor level students at that university, the bridging course is the first time where they are immersed in the university environment and experience a style of teaching mathematics that is markedly different from school. According to the course description[1], the aim of the bridging course is to review mathematical competencies taught at school and to strengthen operational skills to the level expected from incoming students at that university. MP2 was scheduled two months into the semester as we expected that, within this period, the students have become familiar with their new environment at university.

Our sample consists of 428 incoming students enrolled in various bachelor's degree programs in STEM fields (e. g., civil engineering, computer science, electrical engineering, mechanical engineering, technical chemistry, technical mathematics, technical physics). As shown in Table 1, the reliability of the scales used was sufficient ($\omega > .6$) and for the most part very good ($\omega > .8$).

Analysis

To test the hypotheses, we conduct repeated-measures analyses of variance (ANOVA) between the two measurement points and contrast the developments between gender (female: $N = 114$; male: $N = 310$) as between-subject factor. Due to the low occurrence, we did not include participants who indicated their gender as diverse ($N = 2$), preferred not to declare their gender ($N = 2$).

For testing the hypothesis regarding the overall development between the two measurement points, we report the main effect of each construct over time. To examine the hypotheses regarding gender differences, we report within-subject effects as interactions of the gender variable with the development of the constructs. We use the Pearson correlation coefficient r to interpret the effect size of the developments (small: $r = .1$, medium: $r = .3$, large: $r = .5$).

Results

The results show that all the measured value beliefs of incoming students decrease significantly during the first weeks at university (see Table 2, column "Time"). The decrease of students' general utility value of mathematics has large effect size. Students' perception of the utility of mathematics for their future job decreases with medium effect size. While no gender differences are seen in the latter dimension of utility (see Table 2, column "Time * Gender"), the general utility value of mathematics decreases statistically significantly stronger among female students ($M_{MP1} = 4.46$; $M_{MP2} = 3.68$) than among male students ($M_{MP1} = 4.45$; $M_{MP2} = 3.90$).

[1] see https://www.tuwien.at/studium/studieren-an-der-tuw/akmath/allgemeines (retrieved April 26, 2023)

Intrinsic value also decreases with a large effect size; gender comparisons (see Figure 1, left) show a statistically significant difference in favour of male students (M_{MP1} = 4.35; M_{MP2} = 3.94) compared to female students (M_{MP1} = 4.48; M_{MP2} = 3.79).

Table 2: Results of repeated-measures ANOVA with gender contrasts

Construct	MP1	MP2	Time			Time * Gender	
	M (SD)	M (SD)	F	df_R	r	F	r
General utility	4.45 (0.94)	3.84 (1.17)	132.87	401	.50***	3.89	.10*
Utility for job	5.12 (0.86)	4.64 (1.20)	57.39	401	.35***	0.02	<.01
Intrinsic value	4.39 (1.03)	3.90 (1.23)	119.18	398	.48***	7.54	.14**
Importance of achievement	4.53 (1.00)	3.95 (1.22)	114.64	399	.47***	7.97	.14**
Personal importance	4.16 (1.02)	3.80 (1.18)	54.62	401	.35***	1.27	.05
Effort required	3.21 (1.06)	4.03 (1.16)	219.97	401	.60***	1.80	.06
Emotional cost	2.25 (0.91)	2.90 (1.14)	160.42	399	.54***	2.09	.07
Opportunity cost	2.98 (1.06)	4.09 (1.14)	337.79	401	.68***	4.18	.10*
Self-efficacy	4.15 (1.00)	3.60 (1.29)	92.73	401	.43***	7.02	.13**

Note. M…mean value, SD…standard deviation, F…ANOVA test statistics, df_R…degrees of freedom of residuals, p…significance, r…Pearson correlation coefficient; * $p < .05$, ** $p < .01$, *** $p < .001$

The components of attainment value examined in this study also drop statistically significantly. The importance of achievement decreases within the first few weeks at university with a large effect size; the decrease in personal importance of mathematics is of medium effect size. Controlling for gender reveals that the development of the importance of achievement among the male students (M_{MP1} = 4.47; M_{MP2} = 3.98) is again statistically significantly better than among the female students (M_{MP1} = 4.70; M_{MP2} = 3.86).

All three aspects of cost increase with very high effect sizes. A statistically significant difference is found in opportunity cost where cost increases stronger among female students (M_{MP1} = 2.89, M_{MP2} = 4.19) than among male students (M_{MP1} = 3.01, M_{MP2} = 4.05).

The pattern observed in the value beliefs is also found in the expectancy component. The decrease in self-efficacy is of medium to large effect size. The comparison between genders shown in Figure 1 (right) is in favour of male students, whose self-efficacy decreases statistically significantly less (M_{MP1} = 4.21, M_{MP2} = 3.75) than the self-efficacy of female students (M_{MP1} = 4.00, M_{MP2} = 3.19).

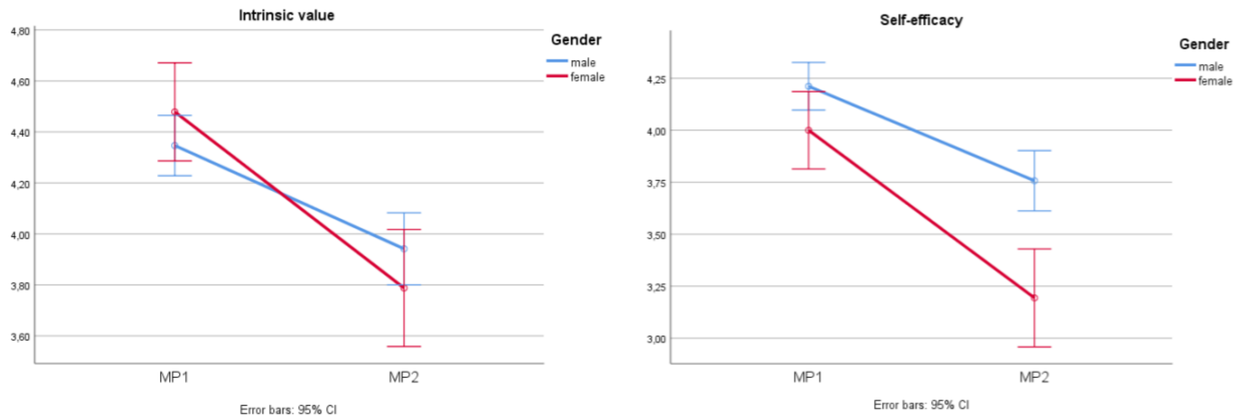

Figure 1: Gender differences in the development of intrinsic value (left) and self-efficacy (right)

Discussion

This study investigates the development of beginning students' expectancy of success in mathematics and their value beliefs about mathematics. The findings show a striking decrease of value and expectancy beliefs within a few weeks at university. This trend is seen in all aspects measured. This suggests, on the one hand, that the general downward trend in achievement motivation seen at school continues at the higher education level, even if beginning students mostly represent a highly positively selected subgroup of students regarding their achievement motivation in mathematics. This selection of motivated students might, at the same time, be a reason why such strong decreases occur: While the students had been used to being successful and among the top performing students in mathematics at their respective schools, they base their self-assessment on comparison with a new peer group who, other than at school, exhibit a relatively high self-concept as well as competence in mathematics (see also Di Martino et al., 2022).

Notably, the results consistently show increases in the standard deviations of the constructs over the first weeks at university, suggesting that expectancy of success and value beliefs of students are less uniform after a few weeks at university than they were at the beginning. This, in turn, indicates that the development of a substantial subgroup of students might not follow the general trend and be able to keep up a high level of expectancy and value beliefs. This finding calls for investigations of subgroups in further research, possibly by carrying on the person-centred approaches employed by Lazarides et al. (2022) and Schweder and Raufelder (2022) at the level of secondary education to the context of higher education. To further discern the trend in expectancy and value beliefs, replicating the study with a third measurement point could substantiate the results of this study.

We should note that the schooling of the great majority of participants in our study was affected by the COVID-19 pandemic, which might have weakened the stability of students' self-concept and limit the validity of our findings to this specific setting. In this context, we note that during the period of distance learning in Austria female students reported higher intrinsic value than male students (Korlat et al., 2021). However, the study of Korlat et al. (2021) is not specific to the context of mathematics.

A substantial proportion of the participants of MP1 could not be reached at MP2. A check for selection effects shows that students who participated only at MP1 (N = 282) had statistically significantly ($p < .05$) less favourable value beliefs than those who participated at both measurement points (N = 428); no statistically significant difference is seen in self-efficacy. Except for importance of achievement, the beliefs of students who participated only at MP2 (N = 75) did not differ statistically significantly from those who participated at both measurement points. The fact that the students who could not be reached after MP1 held less favourable self-beliefs suggests that unfavourable self-beliefs are related to early dropout. Other reasons could be a lack of information or of motivation to participate in the study.

Despite efforts towards gender equity in STEM fields, the results of our study suggest that male students' value beliefs and expectancy beliefs develop more favourably at the secondary-tertiary transition than those of female students. Even though no statistically significant difference could be found in four of the investigated aspects, five aspects did show a difference – all in favour of male students. This suggests that gender differences in favour of male students seen in schools (e. g., Lazarides et al., 2022; Oppermann et al., 2021; Watt et al., 2019) continue in tertiary education and thus need to be addressed by research institutions. Regarding self-efficacy, the gender bias reported in the large-scale review of Huang (2013) was replicated in our study at a single institution. Self-efficacy as well as those value aspects that are related to intrinsic motivation showed the differences with the largest effect sizes. According to Jerusalem and Mittag (1995), these aspects are all indicative of confidence and persistence in the face of challenges, and thus of particular importance for a successful secondary-tertiary transition.

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Research article 3: The development of mathematics expectancy-value profiles during the secondary-tertiary transition into STEM fields

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Research article 3 examines the trends in the motivation of students at the secondary-tertiary transition (RG2). It extends the broad findings of research article 2 by a more fine-grained analysis of the collected data. The findings of research article 2 show a strong decline of student motivation during the secondary-tertiary transition as well as gender differences in favor of male students. The results suggest that the challenges of the secondary-tertiary transition affect various subgroups to different degrees. To obtain a better understanding, this article examines expectancy-value beliefs of students and contextual variables as well as the changes therein over the two measurement points for prevalent patterns using a person-oriented approach. Applying this approach, prevalent patterns in the manifestations of expectancy-value beliefs—so-called "profiles"—could be identified and examined for relations to contextual variables.

Drawing on the same dataset as research article 2, the responses of 409 students who completed the survey at both measurement points were used for analysis. Latent profile analysis (Asparouhov & Muthén, 2014) with *utility for job*, *personal importance*, *intrinsic value*, *opportunity cost*, and *self-efficacy* as profile variables was employed to identify profiles separately at the two measurement points. Additionally, latent transition analysis (Asparouhov & Muthén, 2014; Masyn, 2013) was performed to identify patterns in how students transition from their initial profile at the beginning of the bridging course to their posterior profile two months into the first semester.

Latent profile analysis revealed four distinct profiles at each measurement point, ranging from highly favorable to highly unfavorable. The profiles at the first measurement point ("initial profiles") were labeled *high all except low cost*, *high extrinsic*, *medium all* and *low intrinsic, high extrinsic*. The distribution of students showed high percentages in the two most favorable profiles, making up almost 80% of the sample. The nature of these profiles was slightly different at the second measurement point ("posterior profiles"), resulting in profiles labeled *high all except medium cost*, *high extrinsic*, *medium all*, and *low motivation, high cost*. The percentage of the two most favorable profiles was slashed to 63%. The transition probabilities retrieved from latent transition analysis showed that students would most likely either stay in their profile or transition to the moderate profiles *high extrinsic* and *medium all*. The examination of the profiles with contextual variables showed that, with one exception, the grade in the school leaving examination differed statistically significantly between the profiles. There were no statistically significant differences in the prevalence of types of secondary schools between the four initial profiles and the four posterior profiles. The score in the final exam of the bridging course as a proxy for university achievement was statistically significantly higher in the most favorable posterior profile compared to the two intermediate posterior profiles.

The study showed that cost increased independently of the profile suggesting that students had to invest more time into their bachelor programs than they had been used to. Students in the most adaptive profile were also those with the highest prior achievement; they also had the best exam results in the final exam of the bridging course. Except for a slight increase in cost, they do not seem to face serious challenges at the secondary-tertiary transition. In most profiles, utility value is a manifest source of motivation. Therefore, it is important that the benefits and the utility of mathematics for potential future occupations are recalled to students and emphasized at the beginning of STEM bachelor programs. To keep the motivation of students, in particular for those in the maladaptive profiles, they should have plenty of opportunities to earn a sense of accomplishment to foster their self-efficacy and, subsequently, their persistence in the face of challenges.

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The development of mathematics expectancy-value profiles during the secondary–tertiary transition into STEM fields

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Abstract

Background To master the secondary–tertiary transition into fields of science, technology, engineering, and mathematics (STEM), academic self-beliefs play a pivotal role, especially those related to learning mathematics. The framework of expectancy-value theory has been used widely in primary and secondary education and partly in tertiary education to assess the self-beliefs of students in terms of expectancy of success and perceived value of mathematics. Based on this framework, we measured how the intrinsic value, the attainment value, the utility value, and the cost of learning mathematics as well as the expectancy of success when learning mathematics developed during the secondary–tertiary transition of students into STEM fields. Data were collected in a quantitative repeated-measures questionnaire study with two measurement points (measurement point 1: $n=710$, measurement point 2: $n=487$, listwise: $n=409$). We conducted a latent profile analysis to identify the prevalent patterns of mathematics self-beliefs, called *profiles*, at each of the two measurement points. We studied the relation of these profiles to prior education, achievement at school, and achievement at university. By performing a latent transition analysis, we determined the probabilities of transitioning from the initial profiles to the posterior profiles.

Results Our analysis revealed four distinct prevalent profiles at each measurement point, ranging from highly favorable (i.e., high expectancy, high value, low cost) to highly unfavorable with respect to learning mathematics. The profiles with favorable manifestations remained stable over time, while those with undesirable manifestations deteriorated further. We observed a sharp increase in cost across all profiles. Prior achievement correlated strongly with profile membership.

Conclusions The expenditure of time and energy increased sharply during the secondary–tertiary transition, independently of the students' initial motivational patterns. The perceived utility of mathematics for potential future careers was shown to be a significant source of motivation. The role of mathematics in future careers should thus be made visible in university teaching. Keeping the detrimental development of initially undesirable motivational profiles in mind, university teachers should create ample opportunities for students to gain a sense of accomplishment.

Keywords Academic achievement, Expectancy-value theory, Latent profile analysis, Latent transition analysis, Mathematics, Secondary–tertiary transition, Self-beliefs

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Introduction

The availability of a workforce trained in the fields of science, technology, engineering, and mathematics (STEM) is a key prerequisite for economic growth and competitiveness. Beyond this, STEM education has been linked to promoting societal well-being and equity (Ng, 2019; Walker, 2015). International organizations have identified a worrisome decline in STEM participation and call for measures to counteract this trend (see, e.g., Marginson et al., 2013). Governments are therefore well advised to encourage youths to pursue STEM careers. Heublein et al. (2017) have shown that an alarmingly high proportion of young adults who enter tertiary education in a STEM field do not follow through, identifying problems in performance and lack of study motivation as the main reasons. In particular, the rate of dropout from STEM field degree courses has been reported to be at a very high level in Germany (50% between 2016 and 2020; Heublein et al., 2022) and Austria (56% between 2010 and 2020; Statistics Austria, 2022). It is therefore important to identify beginning STEM field students who have the potential to succeed but are at risk of quitting and to support them.

It has been observed that students on career paths in STEM fields are at a particularly high risk for dropout soon after transitioning from secondary school to higher education (Heublein et al., 2017). This becomes apparent in their mathematics self-concept. For example, Di Martino et al. (2023) showed that, while the mathematics self-concept of students entering mathematics degree courses is typically high initially, they soon tend to adopt less favorable self-beliefs. Notwithstanding individual differences, the school mathematics self-concept of students has been found to remain stable at the transition, while both their general self-concept and university mathematics self-concept tend to decrease (Rach et al., 2021). The decline in mathematics self-concept has repeatedly been attributed to the big-fish-little-pond effect (Marsh, 1987) in empirical works (e.g., Loyalka et al., 2018; von Keyserlingk et al., 2020). This effect is caused by changes in the peer group: High-achieving students in school perceive themselves as superior because their abilities surpass the average level of their peers. Consequently, they develop a high academic self-concept. However, when these students transition to university, their reference group changes. University students typically exhibit higher average levels of ability than their school peers, which results in a decrease in their self-concept.

In non-STEM fields, an increase in favorable autonomous motivation has been observed in the course of higher education (e.g., Kyndt et al., 2015; Ratelle et al., 2004). At the same time, less favorable controlled motivation has been found to remain stable (e.g., Kyndt et al., 2015) or even to decrease (e.g., Ratelle et al., 2004). Kyndt et al. (2015) found unfavorable amotivation to decrease at the secondary–tertiary transition and to remain stable thereafter.

Comparing these results with the high dropout rates in higher education suggests that the findings of Kyndt et al. (2015) and Ratelle et al. (2004) might be specific to students who have already overcome potential challenges and remain in their respective degree programs. This potential positive selection bias as well as the lack of STEM focus in prior studies call for a closer look at the development of motivational aspects of subgroups of students. Expectancy-value theory is a framework for measuring aspects such as achievement-related choices and persistence. It is a particularly suitable framework to study the secondary–tertiary transition, where many achievement-related choices are made and where persistence is crucial for success. Research based on expectancy-value theory using person-centered approaches has been conducted in primary, secondary, and tertiary education (e.g., Lazarides et al., 2022; Perez et al., 2023; Schweder & Raufelder, 2022).

In this study, we adopt a person-centered repeated-measures approach to identify prevalent patterns of self-beliefs related to learning mathematics during the secondary–tertiary transition of students into STEM fields and capture their development, all through the lens of expectancy-value theory.

Expectancy-value theory

Expectancy-value theory (Atkinson, 1958; Eccles, 1983; Eccles & Wigfield, 2020) is a framework that has been used widely to measure self-beliefs of students, and thus to predict achievement motivation, performance, persistence, and achievement-related choices. Expectancy beliefs refer to the subjective assessment of the chance of success or failure when participating in achievement-oriented tasks (Spence & Helmreich, 1983). Expectancy of success is a domain-specific determinant of behavioral choice with respect to education and career (Eccles, 1983). Students with high expectancy of success, as measured by their level of self-efficacy, also exhibit high engagement and persistence (Scherrer & Preckel, 2019). The value component may be described as “the degree of anticipated satisfaction or pride in succeeding at a task or the degree of anticipated shame in failing” (Spence & Helmreich, 1983, p. 33). Four value beliefs can be differentiated: intrinsic value (sense of joy when performing a task), attainment value (personal importance of doing well at a task and personal relevance of a task or a domain), utility value (perceived usefulness of engaging in a task or a domain), and cost (undesirable consequences of engaging in a task). Intrinsic value and attainment value are closely tied to intrinsic motivation, while utility value is related to extrinsic motivation (Trautwein et al., 2013). Intrinsic motivation, in turn, has been shown to be closely related to academic achievement (Scherrer & Preckel, 2019).

The role of expectancy-value theory in STEM education

The claim that expectancy of success and value beliefs are "the most proximal psychological determinants of task and activity choice, performance, and engagement in the chosen activities" (Eccles, 1983) is the bedrock of expectancy-value theory. In the context of learning mathematics, Trautwein et al. (2012) confirmed the potential of the expectancy-value model to predict achievement in mathematics among students in grade 13 of German high schools. In their study, they found expectancy-value beliefs related to learning mathematics to correlate strongly with school type and little with gender or prior achievement. Harackiewicz et al. (2012) showed that a utility-value-based intervention led to increased persistence of students in taking STEM university courses. Thus, high expectancy of success and value beliefs are desirable for learning mathematics in the sense that they are positively related to both performance and persistence, which play an important role for a successful secondary–tertiary transition into STEM fields. In addition, expectancy-value aspects were found to predict the development of computational thinking skills (Jiang et al., 2024).

Person-centered approaches applying expectancy-value theory

Numerous works have applied expectancy-value theory in person-centered approaches to investigate the extent to which expectancy-value profiles predict achievement in the context of primary and secondary education as well as the evolution of such profiles and the transitions between them over time. Schweder and Raufelder (2022) observed across various subjects that self-directed learning sequences led students in grades 6 to 9 to transition to more desirable expectancy-value profiles. By contrast, in their study without a specific intervention, Lazarides et al. (2022) found that expectancy-value profiles of mathematics learners from grade 9 to 10 were mostly stable.

Fong et al. (2021) studied the development of 23,000 students from grade 11 of high school until three years after graduation in the United States. Five distinct expectancy-value profiles were identified: low math/low science; high math/low science; low math/high science; moderate math/moderate science; high math/high science. As one would expect, the high math/high science profile had the highest math grade point average (GPA), science GPA, and academic persistence rate, while the students with low math/low science profile showed the lowest academic results within the cohort. Students in the low math/high science profile and in the moderate math/moderate science profile showed statistically significantly lower persistence in tertiary education than their peers with high math/high science profile.

Studies which combine expectancy-value theory with person-centered approaches in the context of tertiary education are scarce. A notable exception is the study of Perez et al., (2019b) who investigated expectancy-value profiles of students in STEM fields upon their arrival at a highly selective private university in the United States. GPA and course completion rate in STEM majors were recorded at the end of the first and at the end of the fourth year at university. The first-semester profile with high expectancy and value beliefs and low effort cost had significantly higher GPA and course completion rates than the profile with moderate expectancy, value, and cost beliefs. The authors did, however, not investigate how the profiles of individual students evolved in the course of their respective degrees. In a more recent study, Perez et al. (2023) identified four distinct expectancy-value profiles of first-year and second-year chemistry students. The by far most prevalent profile of students with high confidence and low to moderate costs showed the best outcomes in the final exam of a chemistry course.

Summary of the state of research

The essence of available studies which apply expectancy-value theory using person-centered approaches is that more desirable profiles exhibit better academic achievement and persistence. Longitudinal studies showed that profiles remain mostly stable under stable conditions, but transitions between profiles of different shape appear more frequently after interventions. Two studies created profiles only at a single point of time and observed the development of outcome variables but did not investigate whether the profiles changed over time. While all these studies applied expectancy-value theory either in the context of primary or secondary education or in very specific contexts of tertiary education, there is a lack of studies that investigate the development of expectancy-value profiles at the secondary–tertiary transition, in particular of students in STEM fields. As for tertiary education, the relationship between individual expectancy-value aspects and school type or prior achievement has been examined, but the relations of these variables with expectancy-value profiles are still to be investigated.

Our study aims to add the perspective from the secondary–tertiary transition by attempting to answer the following research question: How do the motivational patterns of beginning STEM field students develop during their first semester at university?

The present study

The goal of this work is to identify the prevalent expectancy-value profiles among beginning STEM field students first upon arrival at university (*initial profiles*) and then after the first two months at university (*posterior profiles*). We study the transitions of students between these profiles during the initial phase of their degrees and how these profiles relate to prior education and achievement.

Specifically, we operationalize the general research question stated above by the following concrete research questions (RQs) and corresponding hypotheses:

(RQ1) What are the initial and posterior expectancy-value profiles of STEM field students?

Previous findings (Jiang & Zhang, 2023; Perez et al., 2019b) have led us to hypothesize that we would find initial profiles with high intrinsic and extrinsic value beliefs, high expectancy beliefs, and low cost (H1a) as well as complementary profiles (H1b). Regarding posterior profiles, we hypothesize that the prevalent profiles would show high extrinsic value beliefs, low expectancy beliefs, and high cost (H1c), while profiles with high intrinsic value beliefs, high expectancy beliefs and low cost (H1d) would also be found.

(RQ2) How are the initial profiles related to prior academic achievement and school type?

In view of the high mathematics self-concept which is typically held by beginning STEM field students (Di Martino et al., 2023) as well as previously observed positive correlations between prior achievement and expectancy-value beliefs (Trautwein et al., 2012), we hypothesize that higher prior academic achievement is characteristic of profiles with high expectancy and value beliefs and low cost (H2a). Since the educational pathways in Austria which lead to university admission vary considerably, we hypothesize that there are initial differences in the expectancy-value beliefs of students who graduated from academic secondary schools and those of students who graduated from Higher Federal Technical Colleges. Academic secondary schools follow a broad educational model with a focus on preparation for university education, which leads us to hypothesize that they initially hold more adaptive expectancy-value beliefs than their fellows graduating from Higher Federal Technical Colleges (H2b).

(RQ3) How are the posterior profiles related to academic achievement and school type?

We hypothesize that the posterior profiles of students who graduated from schools of different type would not differ significantly (H3a). By contrast, we hypothesize that profiles with higher expectancy and value beliefs would tend to show higher achievement at university than other profiles (H3b).

Methods

This work is based on a repeated-measures questionnaire study with two waves that comprises scales on expectancy-value constructs, conceptions of mathematics, and learning strategies. The specific focus of this paper is to identify prevalent patterns of expectancy-value aspects among students at the secondary–tertiary transition into STEM fields. These patterns of observable variables (i.e., the expectancy-value aspects; see section "Measures"), subsequently referred to as *profiles*, are modeled as a latent variable. Since we hypothesize that there are several different distinct patterns of observable variables, even though these patterns are not observable directly, we adapt a latent model approach. As a result, each student is assigned to the profile that best fits their individual motivational pattern. Finally, we examine to which extent students remain in their original profile or transition to a different profile using latent transition analysis.

Study design

The data collection at measurement point 1 (MP1) took place in the first session of the preparatory course for incoming students offered by TU Wien, Austria, in September 2022. Though voluntary, participation in this course was strongly recommended by the university. The course focused on the topics functions, vector algebra, complex numbers as well as differential and integral calculus. While the core aspects of the course were the same for all participants, students enrolled in a computer science degree course went through a slightly different course program than the other students. Students received credits for the successful completion of the course. We chose to collect data during this course over approaching students electronically or in an asynchronous setting. Indeed, this would likely have resulted in a selection bias, with participation chiefly by the most diligent students. The students were shown a video at the beginning of the preparatory course in which the authors invited them to participate in the study and explained the procedure and the aim of the study. To increase the readiness of students to participate in the study, vouchers for the university's bookstore were raffled among the participants. Participation in this study was voluntary and subject to informed consent of the students. The questionnaire was provided in German language.

The questionnaire was administered to the students for a second time (MP2) roughly two months into the winter

Table 1 Constructs on expectancy and value beliefs included in the questionnaire, corresponding reliabilities (McDonald's ω), and descriptive statistics

Construct	Items	Sample item	ω		M (SD)	
			MP1	MP2	MP1	MP2
Expectancy						
Self-efficacy	3	I am convinced that I can understand even the most difficult mathematical material presented in the lectures.	0.86	0.89	4.14 (1.01)	3.58 (1.29)
Value beliefs						
Intrinsic value	3	I like doing math.	0.92	0.93	4.37 (1.04)	3.88 (1.24)
Attainment value						
Importance of achievement	3	It is important to me to be good at math.	0.87	0.90	4.52 (0.99)	3.93 (1.24)
Personal importance	3	Math is very important to me personally.	0.85	0.89	4.14 (1.02)	3.79 (1.19)
Utility value						
General utility value	2	Math is very useful to me.	0.66[a]	0.71[a]	4.44 (0.95)	3.84 (1.16)
Utility for job	3	Being good at math will pay off for my professional future.	0.90	0.95	5.11 (0.87)	4.64 (1.21)
Cost						
Effort required	3	Learning math exhausts me.	0.85	0.87	3.22 (1.08)	4.04 (1.16)
Emotional cost	3	When I deal with math, I get annoyed.	0.73	0.79	2.26 (0.92)	2.91 (1.16)
Opportunity cost	3	I have to give up a lot to do well in math.	0.83	0.86	2.98 (1.07)	4.09 (1.15)

$n_{MP1}=409$, $n_{MP2}=409$; *M* mean, *SD* standard deviation, *MP* measurement point

[a] To assess the reliability of the two-item scale, the Spearman–Brown coefficient was used instead of McDonald's ω

term via email. During this period, students did not sit major exams, which may serve as a trigger for dropout. We chose to limit the period between the measurement points to two months to avoid drawing a highly positively selected sample while still capturing the transition period. To enhance the response rate, large cohorts of the sample were given time to fill in the questionnaire in lectures of their respective degree courses.

Participants

710 students participated in the survey at MP1, and 487 students participated at MP2. The responses of the 409 students (age: range = 17–57 years, $M=19.9$ years, SD = 3.0 years) who completed the questionnaire at both measurement points were the basis for data analysis. In the resulting sample, 292 participants identified as male (71.4%), 111 as female (27.1%), 2 as diverse (0.5%), and 4 participants provided no answer to the question on gender (1.0%). 87.8% completed their schooling in Austria and 95.6% in the period between 2019 and 2022. The prevalent Austrian school types[1] attended by these participants were academic secondary schools (51.0% of the students graduating in Austria) which focus on general education and usually comprise four years at the upper secondary level or Higher Federal Technical Colleges (41.8%) which offer specialized education in STEM fields over five years. All the participants enrolled in a degree program in STEM fields (e.g., Civil Engineering, Computer Science, Electrical Engineering, Technical Chemistry, Technical Mathematics, Technical Physics). 88.7% started a degree program at university for the first time. Three out of four students (75.0%) had family members with university experience. Almost all the participants (97.1%) studied full-time.

Measures

To survey students' various value beliefs and expectancy of success in learning mathematics, we used scales from the validated German questionnaire of Gaspard et al. (2021) (see Table 1). Specifically, utility value was measured by the subscales *general utility value* and *utility for job*, attainment value was measured by the subscales *importance of achievement* and *personal importance*,

[1] For an overview of the school types in Austria see https://www.bildungssystem.at/en/.

intrinsic value was measured by the subscale *intrinsic value*, and cost was measured by the subscales *effort required*, *emotional cost*, and *opportunity cost*. Expectancy was measured using the subscale *self-efficacy*. For estimating the reliability, McDonald's ω was computed for each scale at each measurement point. The results show acceptable reliability ($\omega > 0.6$) for general utility value and emotional cost and excellent reliability ($\omega > 0.8$) for all the other scales.

Items which had originally been designed for the context of studying mathematics in schools were adapted to the university context. Each item was surveyed using a six-point Likert scale with 1 representing the lowest level of agreement ("do not agree at all") and 6 the highest level of agreement ("totally agree"). In the questionnaire, the respondents were repeatedly reminded that they should focus their personal attitudes towards mathematics when answering the questions.

As control variables, we inquired the students' grade in the national school leaving examination and asked the participants for their consent to use their scores in the exam which they would take after concluding the preparatory course in our research. This final exam consisted of problems with slightly randomized data so the students would not be working on identical problems. Those students who were enrolled in a computer science degree program ($n = 30$) worked on a comparable but slightly different version of the exam than those enrolled in other degree programs ($n = 166$). The scores were recoded to percentages with 100% reflecting the maximum score of 20. The questionnaire also included questions on sociodemographic variables that we report in the subsection "Participants".

Data preparation

The dataset was prepared for analysis using *SPSS 29* and *R 4.3.3*. Data preparation included the deletion of data records with no ID, records of students who were not first-semester students, and students who participated multiple times at the same measurement point based on the ID they provided. Moreover, we identified careless responses based on short duration of survey completion and low standard deviation in the coded responses (i.e., same response to all items) and deleted them. Following this procedure, we arrived at data from 788 students which we used for the data analysis. The individual datasets from the two measurement points were joined based on the students' ID which they provided.

Analysis

To identify the prevalent expectancy-value profiles at each of the two measurement points and the transition of individual students from profiles at MP1 to those at MP2, we opted for latent modeling. For the classification of the expectancy-value profiles, we introduced a categorical latent variable representing the profile to which each student was assigned. We used the scale means of several subscales of the questionnaire as the profile indicators of the expectancy-value profiles. Specifically, we included utility for job as an extrinsic value, personal importance and intrinsic value as intrinsic values, opportunity cost as an aspect of cost, and self-efficacy as the expectancy component.

For data analysis, we considered the responses of 710 students at MP1 and of 487 students at MP2. Of these students, 409 participated at both measurement points. Using *Mplus 8.8* and following Asparouhov and Muthén (2014a), we ran a latent profile analysis (LPA) separately at each measurement point to identify the profiles that best represent the prevalent configurations of expectancy-value variables (see Appendix A). Since this method requires to specify an assumption regarding the variance and covariance structure of the variables within and across the profiles, we constrained the variances to be equal across the profiles and fixed the covariance at 0 within the profiles (see also Masyn, 2013). After identifying the profiles, we performed a latent transition analysis (LTA) following the procedure outlined by Asparouhov and Muthén (2014a) and Morin and Litalien (2017).

Overall, we ran the LPA ten times, namely for solutions with 2, 3, 4, 5, and 6 profiles at each of the two measurement points. To decide on a profile solution (i.e., on the number of profiles) at each measurement point, we reviewed the fit indices which reflect the goodness of classification. A necessary condition for us to accept a profile solution was that at least 5% of the sample would be allocated to each of the profiles and that the average membership probability within each profile would be 80% or more; see also Weller et al. (2020). From the profile solutions meeting these conditions, we selected the solution with the best fit values. In terms of the fit values, we consulted the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), and the Sample-Size Adjusted BIC (SABIC); the smaller the value of these criteria, the better the fit (Weller et al., 2020). We report the strength of relationships between the profile variables at each measurement point in terms of bivariate correlations in Table 2. In the LPA, the probabilities by which a given participant at a given measurement point belonged to a given profile were determined. The better the participants' individual scores aligned with the mean values of a profile, the greater the probability of belonging to that specific profile. For additional, detailed information on the LPA, see Appendix A. After identifying the initial and posterior profiles, we ran a LTA on them. This is a probabilistic approach to examine patterns in the transitions of

Table 2 Bivariate correlations of the profile variables at the first (MP1) and the second measurement point (MP2)

	Construct	1	2	3	4	5	6	7	8	9	10	11	*n*	M	SD
1	Self-efficacy MP1	–											409	4.14	1.01
2	Self-efficacy MP2	0.496***	–										409	3.58	1.29
3	Intrinsic value MP1	0.428***	0.262***	–									409	4.37	1.04
4	Intrinsic value MP2	0.339***	0.512***	0.692***	–								406	3.88	1.24
5	Personal importance MP1	0.342***	0.248***	0.662***	0.544***	–							409	4.14	1.02
6	Personal importance MP2	0.299***	0.505***	0.534***	0.769***	0.657***	–						409	3.78	1.19
7	Utility for job MP1	0.177***	0.068	0.339***	0.214***	0.415***	0.258***	–					409	5.11	0.86
8	Utility for job MP2	0.149**	0.378***	0.288***	0.479***	0.347***	0.584***	0.435***	–				409	4.64	1.21
9	Opportunity cost MP1	− 0.345***	− 0.176***	− 0.396***	− 0.223***	− 0.105*	− 0.127**	− 0.078	− 0.068	–			409	2.98	1.07
10	Opportunity cost MP2	− 0.241***	− 0.472***	− 0.231***	− 0.364***	− 0.100*	− 0.227***	− 0.037	− 0.186***	0.457***	–		409	4.10	1.15
11	School leaving exam (grade)	− 0.181***	− 0.142**	− 0.389***	− 0.306***	− 0.187***	− 0.188***	− 0.096	− 0.114*	0.340***	0.202***	–	356	1.75	0.89
12	Course exam (relative score)	0.046	0.222**	0.049	0.160*	0.069	0.141*	0.045	− 0.009	− 0.023	− 0.131	− 0.333***	196	0.60	0.19

Absolute values of 0.1 can be interpreted as small relationships, absolute values of 0.3 as medium relationships, and absolute values of 0.5 as strong relationships

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

Table 3 Confirmatory factor analysis to test the presumed four-factor model of value beliefs

	CFI	TLI	RMSEA	SRMR
Measurement point 1	0.997	0.996	0.043 [0.028, 0.058]	0.027
Measurement point 2	0.998	0.998	0.041 [0.025, 0.056]	0.025

CFI Comparative Fit Index, *TLI* Tucker–Lewis Index, *RMSEA* root mean square error of approximation (90% confidence interval), *SRMR* standardized root mean square residual

students from the initial profiles to the posterior profiles. Since the LTA uses all the profile membership probabilities, it is able to provide particularly nuanced information on the dynamics of transition between profiles.

The results of the final exam of the preparatory course were available from 47.9% of the participants; denial of consent to process exam results or students not participating in the exam led to this reduced availability of data. Equality tests of means using the BCH procedure were used to test for relationships between profile membership with the grade in the school leaving examination and with the score in the final exam of the preparatory course. The BCH procedure after Bolck et al. (2004) allowed comparisons between profiles while observing measurement errors of the profile variables using weights. For detailed information on this procedure, we refer to the explications of Asparouhov and Muthén (2014b). We used multinomial logistic regression to examine whether the school type predicts profile membership.

To evaluate the construct validity of the scales, we performed a confirmatory factor analysis of all items assumed to measure the value beliefs included in the questionnaire. We checked for sufficient distinctness of the four value beliefs intrinsic value, personal importance, utility for job, and opportunity cost. We used the common fit indices and thresholds (Hu & Bentler, 1999) to infer good model fit (CFI > 0.95, TLI > 0.95, RMSEA < 0.06, SRMR < 0.08). The results showed excellent model fit at both measurement points for the presumed four-factor structure of the value beliefs (see Table 3).

We examined potential selection effects as students who only participated at MP1 might have withdrawn from their degree program. We conducted *t*-tests to compare these students with those who participated at both measurement points.

Results

Latent profiles

Based on multiple information criteria (see Tables 4 and 5), a four-profile model was found to fit the data at both measurement points suitably by the criteria specified in the Analysis section. The subsequent analyses were based on this four-profile model.

Among the initial profiles (see Fig. 1 and Table 6), a profile with highly adaptive manifestation of all constructs, i.e., high expectancy (self-efficacy), high intrinsic value beliefs (intrinsic value, attainment value), high extrinsic value beliefs (utility value), and low cost, was found. We denote this profile as *Initial profile 1* or as the *high all except low cost profile.*

The second most adaptive profile at MP1 differed from Profile 1 in terms of a somewhat lower level of expectancy and intrinsic value beliefs. More than half of the sample holds this profile, which we denote as *Initial Profile 2* or the *high extrinsic profile.*

We also found a less adaptive prevalent profile that had intermediate values in all the five variables, which we refer to as *Initial profile 3* or as the *medium all profile.*

The profile with the most maladaptive manifestation of constructs had low self-efficacy, low intrinsic and high extrinsic value beliefs, and moderate cost. We denote this smallest profile (8.3%) as *Initial profile 4* or as the *low intrinsic, high extrinsic profile.*

Since we specified a model with profile invariant residual variances in our analysis, the variance of corresponding variables is equal in all profiles. Overall, the analysis of the initial profiles has resulted in two adaptive profiles

Table 4 Fit indices for different latent profile solutions at measurement point 1

Profiles	#Par	LL	LL Replicated	AIC	CAIC	BIC	SABIC	Entropy	VLMR	ALRT	Relative profile sizes
2	16	− 2738.9	Yes	5509.8	5590.0	5574.0	5523.3	0.696	0.004	0.005	0.55/0.45
3	22	− 2678.0	Yes	5400.0	5510.3	5488.3	5418.5	0.765	0.100	0.105	0.55/0.31/0.14
4	**28**	**− 2638.5**	**Yes**	**5332.9**	**5473.3**	**5445.3**	**5356.4**	**0.791**	**0.019**	**0.021**	**0.52/0.28/0.12/0.08**
5	34	− 2616.1	Yes	5300.3	5470.7	5436.7	5328.8	0.801	0.260	0.267	0.48/0.22/0.16/0.10/0.04
6	40	− 2597.0	Yes	5274.0	5474.5	5434.5	5307.6	0.807	0.060	0.065	0.45/0.22/0.16/0.09/0.04/0.03

The row set in bold corresponds to the model chosen for the analysis

#Par number of estimated parameters, *LL* log-likelihood, *AIC* Akaike Information Criterion, *CAIC* consistent AIC, *BIC* Bayesian Information Criterion, *SABIC* sample-size adjusted BIC, *VLMR* Vuong–Lo–Mendell–Rubin likelihood ratio test for k versus $k+1$ profiles, *ALRT* Lo–Mendell–Rubin adjusted likelihood ratio test for k versus $k+1$ profiles

Table 5 Fit indices for different latent profile solutions at measurement point 2

Profiles	#Par	LL	LL replicated	AIC	CAIC	BIC	SABIC	Entropy	VLMR	ALRT	Relative profile sizes
2	16	− 3059.1	Yes	6150.1	6230.4	6214.4	6163.6	0.761	< 0.001	< 0.001	0.59/0.41
3	22	− 2957.4	Yes	5958.8	6069.1	6047.1	5977.3	0.811	0.003	0.003	0.53/0.31/0.16
4	**28**	**− 2922.9**	**Yes**	**5901.8**	**6042.2**	**6014.2**	**5925.3**	**0.794**	**0.019**	**0.021**	**0.45/0.27/0.20/0.09**
5	34	− 2900.5	Yes	5869.0	6039.5	6005.5	5897.6	0.747	0.473	0.482	0.29/0.28/0.17/0.16/0.09
6	40	− 2881.5	Yes	5843.1	6043.6	6003.6	5876.7	0.777	0.351	0.357	0.32/0.26/0.16/0.11/0.09/0.05

The row set in bold corresponds to the model chosen for the analysis

#Par number of estimated parameters, *LL* log-likelihood, *AIC* Akaike Information Criterion, *CAIC* consistent AIC, *BIC* Bayesian Information Criterion, *SABIC* sample-size adjusted BIC, *VLMR* Vuong–Lo–Mendell–Rubin likelihood ratio test for *k* versus *k* + 1 profiles, *ALRT* Lo–Mendell–Rubin adjusted likelihood ratio test for *k* versus *k* + 1 profiles

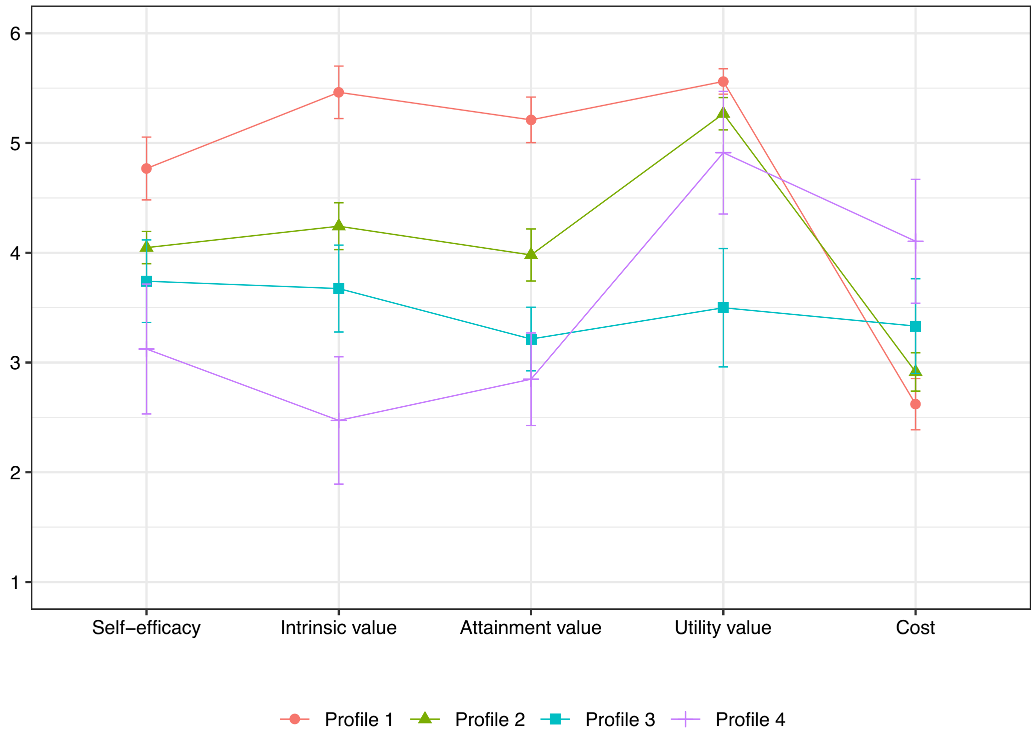

Fig. 1 Comparison of initial profiles. Error bars represent 95% confidence intervals

Table 6 Mean values (*M*) and standard errors (SE) of profile variables by initial profile

Construct	Profile 1		Profile 2		Profile 3		Profile 4		Variance
	M	SE	*M*	SE	*M*	SE	*M*	SE	
Self-efficacy	4.768	0.146	4.047	0.075	3.741	0.192	3.123	0.302	0.801
Intrinsic value	5.462	0.122	4.242	0.109	3.674	0.202	2.472	0.296	0.371
Attainment value	5.211	0.106	3.980	0.121	3.214	0.148	2.848	0.215	0.459
Utility value	5.561	0.059	5.267	0.075	3.499	0.275	4.912	0.285	0.365
Cost	2.620	0.119	2.914	0.089	3.332	0.220	4.105	0.288	0.976
Proportion	28.2%		51.6%		11.9%		8.3%		

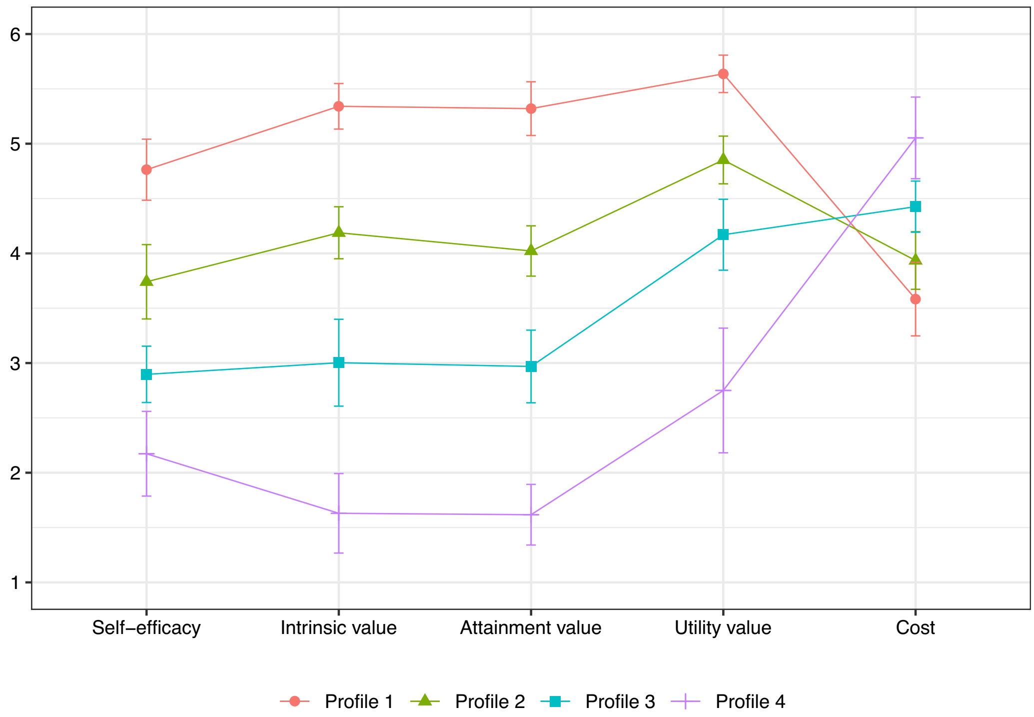

Fig. 2 Comparison of posterior profiles. Error bars represent 95% confidence intervals

(profiles 1 and 2) and two less adaptive profiles (profiles 3 and 4).

The exploration of posterior profiles resulted in profiles that can be compared well to the initial profiles. In general, the range of values of profile variables is larger in the posterior profiles than in the initial profiles (see Fig. 2).

Posterior profile 1 is comparable to Initial Profile 1 but shows higher cost (see Fig. 3). Therefore, we refer to this profile as the *high all except medium cost profile.*

Posterior profile 2 differs from Initial Profile 2 in that it exhibits higher cost and slightly lower utility value. We again refer to this profile as the *high extrinsic profile* (see Fig. 4).

Posterior profile 3 exhibits increased but still moderate utility value and cost compared to the corresponding initial profile (see Fig. 5). We again denote this profile as the *medium all profile.*

In Posterior profile 4, maladaptive manifestations in the corresponding initial profile have been reinforced. While expectancy as well as intrinsic, attainment and utility value beliefs have been reduced, cost has increased (see Fig. 6). We refer to this profile as the *low motivation, high cost profile.*

Profile transition

As can be seen from the proportion of students in each profile (Tables 6 and 7), the proportion of members of Profile 1 and Profile 2 has decreased considerably from MP1 to MP2, while that of Profile 3 has increased significantly. To gain a detailed insight into how students transition from the initial profiles to the posterior profiles, we display the transition probabilities and the proportions of profile members in Fig. 7; Table 8 provides additional information on the transition probabilities.

The probability of remaining in the posterior profile corresponding to one's initial profile is high in general with the exception of staying in Profile 4. Rather, the probability to change from Initial profile 4 to Posterior profile 3 is higher than the probability of remaining in Profile 4, even though not statistically significantly higher ($p = 0.312$). Moreover, the probabilities to transition to Posterior profiles 2 and 3 are substantial, in particular that of transitioning from Initial profile 1 to Posterior profile 2 ($p_{1,2} = 0.40$), which is, however, not statistically significantly lower ($p = 0.196$) than the probability of staying in Profile 1 ($p_{1,1} = 0.57$).

Initial profile membership by exam grade

The school leaving exam grades of students who completed the Austrian school leaving exam differ statistically significantly between the initial profiles ($\chi^2 = 49.07$, $df = 3$,

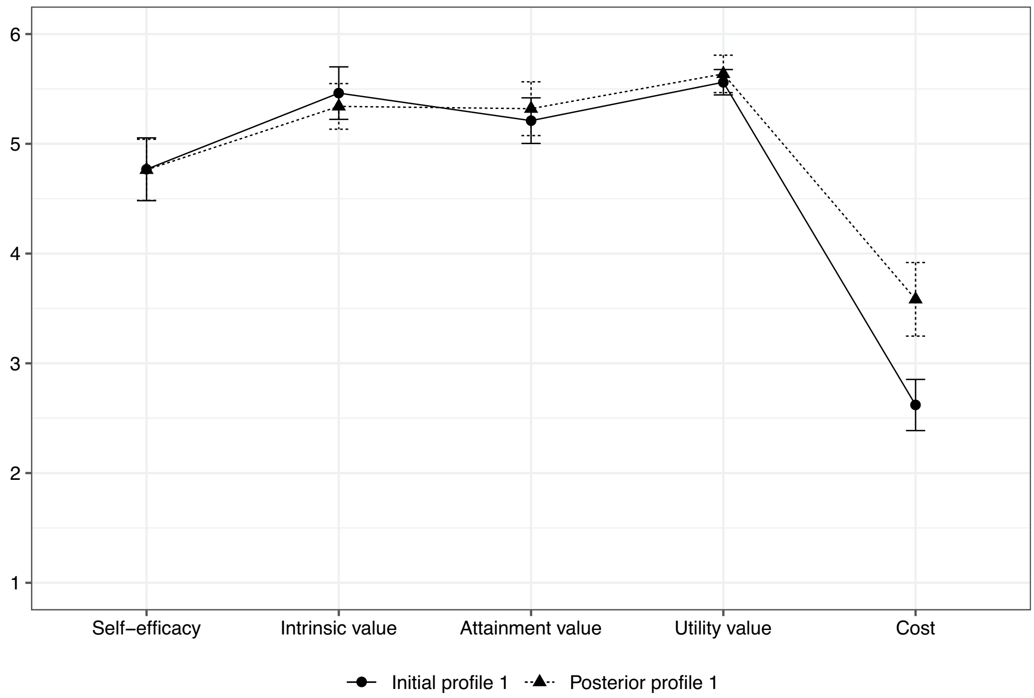

Fig. 3 Development of Profile 1. Error bars represent 95% confidence intervals

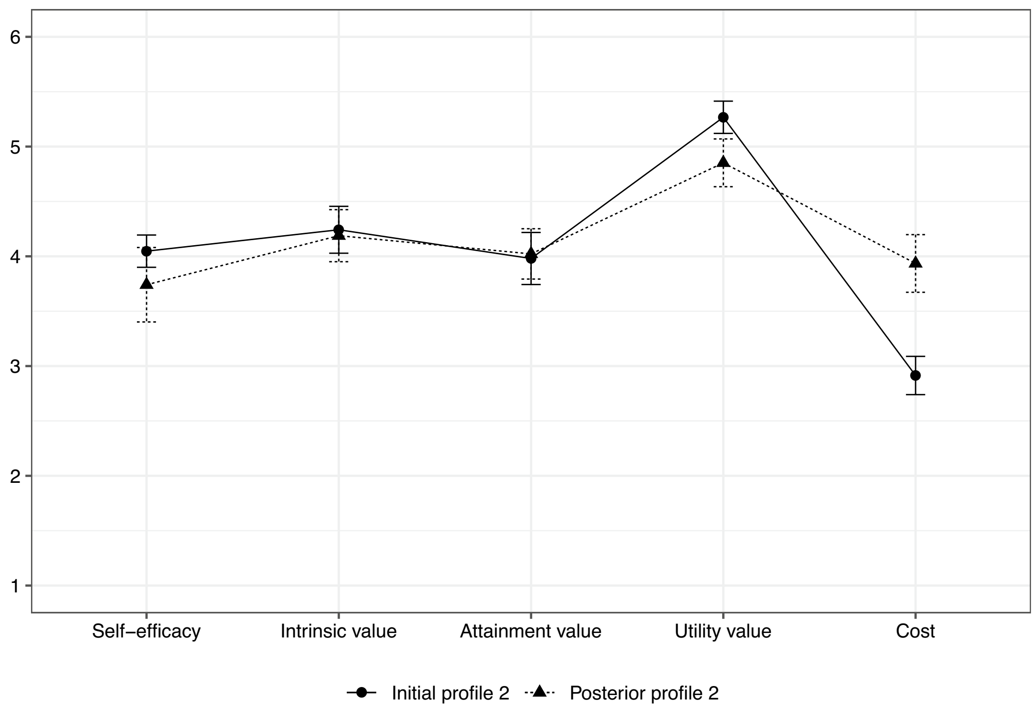

Fig. 4 Development of Profile 2. Error bars represent 95% confidence intervals

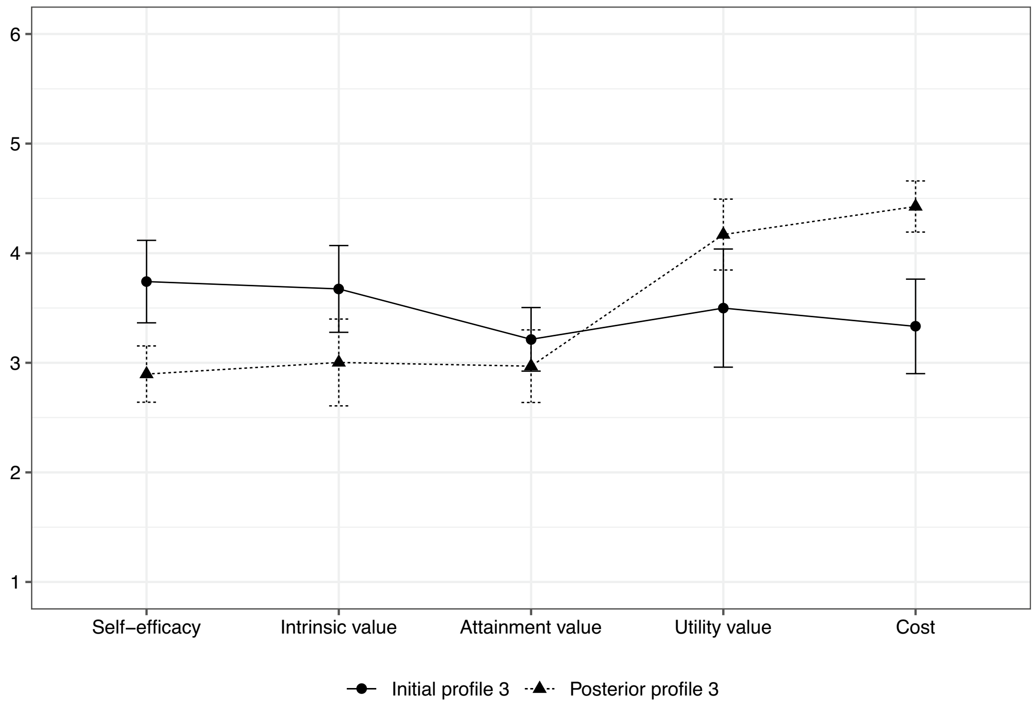

Fig. 5 Development of Profile 3. Error bars represent 95% confidence intervals

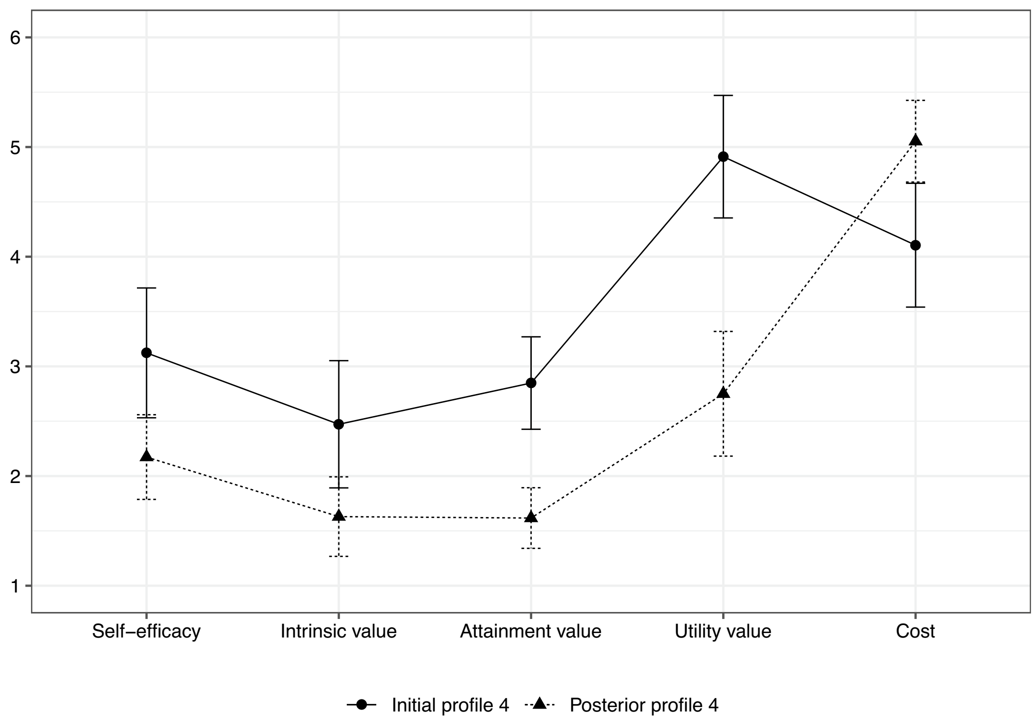

Fig. 6 Development of Profile 4. Error bars represent 95% confidence intervals

Table 7 Mean values (*M*) and standard errors (SE) of profile variables by posterior profile

Construct	Profile 1		Profile 2		Profile 3		Profile 4		Variance
	M	SE	*M*	SE	*M*	SE	*M*	SE	
Self-efficacy	4.763	0.142	3.741	0.173	2.897	0.131	2.173	0.197	1.086
Intrinsic value	5.341	0.106	4.188	0.121	3.003	0.202	1.630	0.185	0.442
Attainment value	5.320	0.125	4.022	0.117	2.969	0.169	1.617	0.141	0.346
Utility value	5.637	0.087	4.852	0.111	4.170	0.165	2.750	0.290	0.880
Cost	3.583	0.171	3.935	0.134	4.426	0.119	5.053	0.190	1.136
Proportion	18.3%		44.8%		27.1%		8.7%		

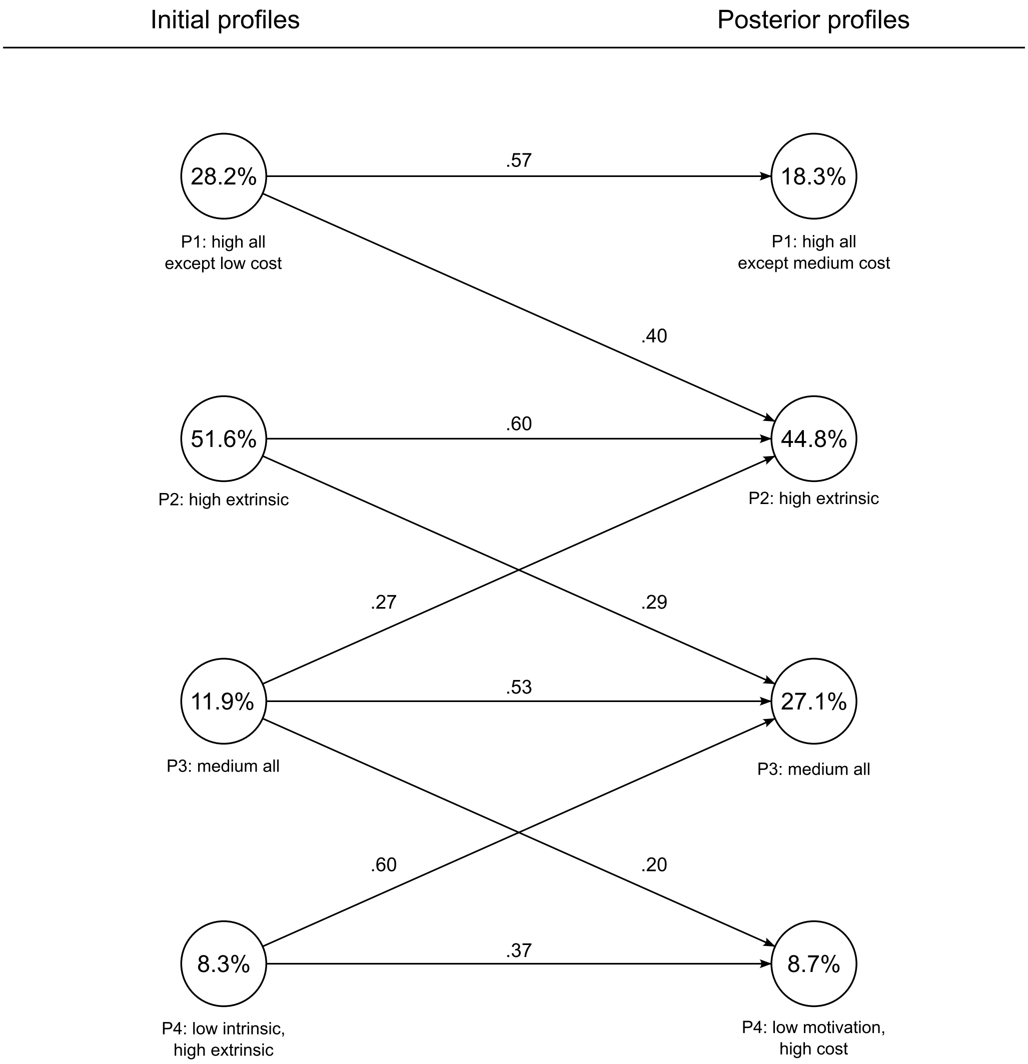

Fig. 7 Transition probabilities (>0.10) between initial profiles and posterior profiles

$p<0.001$). Members of the more adaptive profiles had better grades in their final exams (see Table 9). Equality tests of means across profiles using the BCH procedure reveal that all the differences between the profiles are statistically significant except for the difference between Initial profile 2 and Initial profile 3 (see column "Comparisons" in Table 9).

Table 8 Probabilities and 95% confidence intervals for the transition from initial profiles to posterior profiles

	Posterior Profile 1	Posterior Profile 2	Posterior Profile 3	Posterior Profile 4
Initial Profile 1	0.573 [0.444, 0.693]	0.401 [0.274, 0.542]	0.024 [0.001, 0.314]	0.003 [0.000, 0.948]
Initial Profile 2	0.059 [0.023, 0.147]	0.595 [0.494, 0.689]	0.285 [0.206, 0.381]	0.060 [0.029, 0.120]
Initial Profile 3	0.000 [0.000, 0.000]	0.270 [0.123, 0.494]	0.528 [0.315, 0.731]	0.202 [0.088, 0.400]
Initial Profile 4	0.029 [0.003, 0.237]	0.000 [0.000, 0.000]	0.600 [0.377, 0.789]	0.371 [0.190, 0.597]

Table 9 Average grade (1 = highest, 5 = lowest) in the Austrian school leaving examination by initial profiles

Profile	Grade		Comparisons		
	Mean	SE		χ^2	*p*
1	1.419	0.090	Profile 1 vs. Profile 2	4.956	0.026
			Profile 1 vs. Profile 3	8.585	0.003
			Profile 1 vs. Profile 4	42.619	< 0.001
2	1.696	0.070	Profile 2 vs. Profile 3	2.113	0.146
			Profile 2 vs. Profile 4	28.651	< 0.001
3	1.969	0.166	Profile 3 vs. Profile 4	10.192	0.001
4	2.861	0.202			

$n = 347$

Table 10 Results from multinomial logistic regression of school type on profile membership

Variable	Category	Odds ratio	SE	95% Confidence interval	
Initial profiles					
Profile 1 (ref.)	–	–	–	–	–
Profile 2	ACAD (ref.)	–	–	–	–
	TECH	0.890	0.232	0.534	1.484
	OTHER	0.411	0.202	0.157	1.077
Profile 3	ACAD (ref.)	–	–	–	–
	TECH	1.576	0.618	0.731	3.398
	OTHER	1.469	0.910	0.436	4.946
Profile 4	ACAD (ref.)	–	–	–	–
	TECH	0.472	0.235	0.178	1.251
	OTHER	0.553	0.456	0.110	2.784
Posterior profiles					
Profile 1 (ref.)	–	–	–	–	–
Profile 2	ACAD (ref.)	–	–	–	–
	TECH	1.261	0.386	0.692	2.298
	OTHER	1.142	0.713	0.336	3.880
Profile 3	ACAD (ref.)	–	–	–	–
	TECH	1.359	0.450	0.710	2.601
	OTHER	1.888	1.190	0.549	6.495
Profile 4	ACAD (ref.)	–	–	–	–
	TECH	1.018	0.478	0.405	2.554
	OTHER	1.156	1.059	0.192	6.966

$n = 359$; *SE* standard error, *ACAD* Academic Secondary School ("Allgemeinbildende höhere Schule"), *TECH* Higher Federal Technical College ("Höhere technische Lehranstalt"), *OTHER* other school types

Initial and posterior profile membership by school type

The great majority of participants (87.7%) obtained their permission for higher education in Austria. Results from multinomial logistic regression of the school type on profile membership (see Table 10) reveal that the odds of students from Higher Federal Technical Colleges to be in Initial profile 3 rather than in Initial profile 1 were 1.58 times the odds of academic secondary school students. Contrary to that, the odds of students from Higher Federal Technical Colleges to be in Initial profiles 2 or 4 rather than in Initial profile 1 were 0.89 times and, respectively, 0.47 times the odds of academic secondary school students.

Regarding posterior profile membership, the odds of students from Higher Federal Technical Colleges were higher for being in Posterior profile 2 (1.26 times that of academic secondary school students), in Posterior profile 3 (1.36 times that of academic secondary school students), or in Posterior profile 4 (1.02 times that of academic secondary school students) rather than in Posterior profile 1. We note that the odds ratios are not statistically significantly different from 1 (95% confidence interval).

Posterior profile membership by exam score

Among the participants who completed the final exam of the preparatory course ($n = 196$), we observed statistically significant differences in the exam scores between the profiles ($\chi^2 = 8.057$, $df = 3$, $p = 0.045$). Using the BCH procedure for equality tests of means across posterior profiles, we found that the exam results were statistically significantly higher in profile 1 than in profile 2 and profile 3 (see Table 11).

Checks for selection effects

As for potential selection effects (see Appendix B), the data showed that the 409 students who participated at both measurement points had statistically significantly more favorable intrinsic value beliefs ($t = 3.81$, $df = 697$,

Table 11 Mean relative score (0–1) in the final exam of the preparatory course by posterior profiles

Profile	Exam score		Comparisons		
	M	SE		χ^2	*p*
1	0.672	0.026	Profile 1 vs. Profile 2	6.206	0.013
			Profile 1 vs. Profile 3	4.300	0.038
			Profile 1 vs. Profile 4	2.420	0.120
2	0.577	0.024	Profile 2 vs. Profile 3	0.000	0.986
			Profile 2 vs. Profile 4	0.307	0.579
3	0.578	0.038	Profile 3 vs. Profile 4	0.180	0.671
4	0.601	0.037			

$n=196$, *M* mean, *SE* standard error

$p<0.001$), attainment value beliefs ($t=3.55$, $df=692$, $p<0.001$), and utility value beliefs ($t=2.26$, $df=555.39$, $p=0.024$), as well as lower cost ($t=-2.71$, $df=695$, $p=0.003$) at MP1 compared to those 301 students who participated only at MP1. Self-efficacy did not differ statistically significantly between these groups ($t=0.60$, $df=608.73$, $p=0.549$). The two groups did not differ statistically significantly in age ($t=-1.65$, $df=666$, $p=0.100$) or gender ($\chi^2=1.388$, $df=1$, $p=0.239$). These observations indicate a positive selection of students who were initially in a better position than those who did not participate at MP2. We take up these selection effects and their potential influence on our results in the discussion.

Discussion

In this work, we have gone well beyond observing general trends in the self-beliefs of students at the secondary–tertiary transition which we reported in a recent paper using the same dataset (Mayerhofer et al., 2023). We have identified the prevalent patterns of self-beliefs held by STEM field students during their first semester at university. Our person-centered approach enables us to describe the development of these self-beliefs in terms of transition probabilities between initial and posterior expectancy-value profiles. All profiles exhibit a stable or negative development of expectancy-value beliefs as well as a steep increase in cost.

Resulting initial profiles. The four resulting initial profiles show that the students' self-efficacy, intrinsic value, and attainment value beliefs are all comparably high within each profile. Profiles with high such beliefs correspond to low cost and vice versa. The profiles differ primarily in terms of the level of these beliefs. Interestingly, there are two profiles, the high extrinsic profile (Initial profile 2) and the low intrinsic, high extrinsic profile (Initial profile 4), in which utility value is considerably higher compared to the level of the other beliefs. The students in these two profiles seem to draw their motivation to pursue a STEM field degree program primarily from how they perceive the utility of mathematics for their professional future. High utility value of students in Initial profile 2 is accompanied by sound intrinsic motivation and value of learning mathematics. Notably, this profile accounts for more than half of the sample. The strong perception of the utility of mathematics did not show in profiles of students in grades 6 to 8 (Schweder & Raufelder, 2022), in grades 9 to 10 (Lazarides et al., 2022), or in grade 11 (Fong et al., 2021). We suspect that this perception of the utility of mathematics is a result of considerations of employment prospects at the end of their schooling and might therefore be particularly present at the transition to university. Initial profile 4 was similar to the hypothesized profile low in expectancy and intrinsic value beliefs (H1b) but had high instead of the hypothesized low extrinsic value beliefs and moderate instead of high cost. The make-up of this profile suggests that these students, compared to those in initial profile 2, draw their learning motivation even more from extrinsic incentives such as job aspirations rather than from interest in mathematics. According to the self-determination theory of Deci and Ryan (2015), such extrinsic aspirations correlate with poor psychological health. This could be an explanatory factor for university dropout. Beyond that, low mathematics self-efficacy has been shown to be strongly related to math anxiety (Rozgonjuk et al., 2020) which additionally nurtures dropout intentions.

The initial profiles include the high all except low cost profile, as hypothesized (H1a). Among the four profiles, we consider students in the high all except low cost profile to be in the best position to master the secondary–tertiary transition. From a psychological and developmental point of view, it is desirable for self-efficacy, intrinsic value, and attainment value to be high and for cost to be low.

In Initial profile 3, the manifestation of all measured constructs is moderate. There is no strong tendency either towards more or towards less favorable patterns of self-beliefs.

Resulting posterior profiles. The four posterior profiles that have emerged from the latent profile analysis exhibit greater differences in the profile variables than the initial profiles. This suggests that the self-beliefs of students are initially more uniform or indifferent and then become more varied and explicit in the course of the secondary–tertiary transition.

Posterior profile 1 is highly comparable to Initial profile 1, exhibiting high expectancy and value beliefs and moderate cost. Notably, and different from hypothesis (H1d), cost has increased substantially over time. This is most likely due to higher expectations at university than at school and due to a better understanding as well as a more realistic assessment of the requirements at university. Similarly, profile 2 is stable except for an increase in cost.

Posterior profile 3, besides an increase in cost, exhibits a sharp increase in extrinsic value beliefs, suggesting that the initially indifferent manifestation of intrinsic and extrinsic value beliefs develops in favor of extrinsic beliefs.

While profiles 1, 2, and 3 are essentially stable in expectancy and intrinsic value beliefs, the manifestation of these aspects decreases significantly in Posterior profile 4 compared to the respective initial profile. Cost increases, as in all the other profiles. The increase in cost among first-semester students has also been observed among undergraduate biology students (Perez et al., 2019a). Profiles comparable to the posterior profiles of our study have also been identified among first-semester chemistry students in their third month at a Canadian university with the exception of the low motivation, high cost posterior profile (Lee et al., 2022).

Interestingly, among the posterior profiles, there is no profile showing particularly high extrinsic value beliefs. This is surprising since, according to Deci and Ryan (2015), one would expect that intrinsic motivation is compromised by deadlines and other requirements to proceed further into the degree, which should lead students to adopt extrinsic aspirations, specifically on the utility of a mathematics degree for future employment. Posterior profile 3 comes closest to reflecting this hypothesized pattern (H1c).

Development of profiles. Our results indicate that the profiles remained either stable or developed unfavorably between the two waves. The more adaptive profiles (profiles 1 and 2) maintained the high level of expectancy and value beliefs, while cost increased noticeably. The less adaptive profiles (profiles 3 and 4) underwent significant negative changes. The general negative trend of expectancy may well be accounted for by the big-fish-little-pond effect. As in Perez et al. (2019a), we see that the overall negative trend in value beliefs and cost is driven by the strong deterioration in students with maladaptive initial beliefs. These trends are the more worrisome considering that nonparticipation of students at measurement point 2 resulted in a positively selected sample of students with higher initial value beliefs and better grades in their school leaving examination. This means that the students included in this study are a selection of students who, on average, were already in a desirable motivational starting position. It can be assumed that a considerable proportion of the students who did not participate in the second wave had already dropped out of their respective degree programs.

Transition from initial to posterior profiles. While the students of all initial profiles (except for Initial profile 4) are most likely to remain in a profile comparable to their initial profile, there is a considerable probability to change to a different profile over time. The results of our study clearly indicate that changes of profiles are mostly towards Posterior profiles 2 and 3: There is a 40% probability of changing from Initial profile 1 and a 27% probability of changing from Initial profile 3 to Posterior profile 2. These probabilities do not differ statistically significantly from staying in Profile 1 or, respectively, Profile 3 and are therefore relatively high. The chance of transitioning from Initial profile 2 to Posterior profile 3 is 29% and thus significantly lower than that of staying in Profile 2. Students in Initial profile 4, in turn, are 60% likely to transition to Posterior profile 3. The likeliness of transitioning to the Posterior profiles 1 and 4 is, for the most part, insignificantly small. Overall, there is a strong tendency that students either transition to the posterior profile that corresponds to their initial profile or to transition to the Posterior profiles 2 and 3.

Prior achievement in initial profiles. We have used the grades in the Austrian centralized school leaving exam in mathematics as a proxy for prior achievement. We have found that better grades in this exam correspond to more adaptive initial expectancy-value patterns. The differences in the grades are statistically significant for all initial profiles except for the difference between Initial profiles 2 and 3. This suggests that the mathematics grade in the Austrian school leaving exam positively predicts adaptive expectancy-value patterns and, for the most part, confirms our hypothesis (H2a).

School types in initial and posterior profiles. Our data allowed for comparisons between academic school students and students from Higher Federal Technical Colleges. Since expectancy-value beliefs have been found to be higher among academic school students than among students from vocational schools in their final year at school (Trautwein et al., 2012), we had expected differences in the initial profiles in favor of students having graduated from academic secondary schools (H2b). While there is no apparent tendency in the initial profiles speaking in favor of students from either school type, the results provide some indication that academic school students are more likely to be in the most adaptive posterior profile. This might reflect outcomes from the orientation of upper secondary schools to foster learning strategies and learners' self-beliefs while Higher Federal Technical Colleges provide more specialized education. Since these trends are not statistically significantly different among different school types, they do not fully contradict our hypothesis (H3a).

Academic achievement in posterior profiles. We have used the score in the final exam of the preparatory course as a proxy for achievement in university mathematics. The correlation between the grade in the mathematics school leaving exam and the final exam of the preparatory course suggests that students with better grades in the school leaving exam also achieve better results in the exam of the preparatory course. This relationship appears to be of a small but remarkable effect size and indicates that the achievement in mathematics is to a certain degree stable when comparing assessments at school and at university. In line with our hypothesis (H3b), we have found that better results correspond to more adaptive posterior profiles. No statistically significant differences between profile 4 and the other profiles were found. This may be due to the small number of participants in this profile who had given consent that their exam scores be processed. Reasonable explanations could be that students in this group did not participate in the final exam of the preparatory course, which would be in line with the low manifestation of motivation in this profile, or that these students geared their strategies towards achieving the best possible score while neglecting their progress in mathematics. Overall, the observed relationship between the expectancy-value profiles and the exam score supports the conclusion of Trautwein et al. (2012) that expectancy-value profiles would predict academic achievement.

Limitations and future research

Notwithstanding the contributions of this work, several potential limitations should be kept in mind when interpreting our findings. First, the period between the two measurement points are the first two months of students studying at university. In this period, the students are affected by many different influences, some of which are related to their general life transition rather than to the transition in their educational career. The second measurement point was two months into the first semester so that the period between the two measurement points was short enough to avoid positive selection due to student dropout, for example, because of performance issues and experience of failure, and long enough to capture the trends appearing at the secondary–tertiary transition. This compromise has allowed us to observe meaningful trends while minimizing potential biases.

Second, we chose to run the analysis of latent profiles at MP2 independently of the profiles found at MP1, i.e., the profile variables at MP2 could have mean values and variances different from the corresponding profile variables at MP1, since we aimed to capture the development of profiles over time. This, however, required us to match the initial profiles with the posterior profiles qualitatively using the mean values and variances of the profile variables as indicators.

Third, to derive implications from our results, it seems reasonable to put the profiles in an order. We ordered the profiles by how desirable they are from a psychological perspective. While the order among the posterior profiles can be derived rather directly from the levels of manifestations of the profile variables (see Fig. 2), the order of initial profiles is not unambiguous due to the higher utility value in profile 4 compared to profile 3 while all other variables indicate that profile 3 could be considered more desirable than profile 4, which was decisive for our decision on the order of profiles.

Another limitation is that, for assessing prior achievement, we have only included self-reported grades in the Austrian school leaving exams. Since nearly 90% of the participants graduated from schools in Austria, these grades are, however, sufficiently representative for the whole sample.

In addition, since all participants of our study are students of the same institution, checks for specific institutional effects on our results are not possible.

Finally, it should be noted that the assessment of achievement is based on a mathematics exam that is part of the preparatory course, which most of the participants took at the end of the preparatory course, before the start of their first-semester courses. The scores of these exams can yet be considered as approximately indicative of academic achievement since they reflect to what degree the students were able, on the one hand, to transfer their mathematics knowledge from school to an assessment of their mathematics knowledge at university, and, on the other hand, to adapt to the nature of assessments at university. It remains a desideratum for future research to investigate how academic achievement and persistence develop in the long term in the respective profile.

Since the overall socio-economic background of schools has been found to be related to academic achievement (e.g., Rozgonjuk et al., 2023), it would be worthwhile to investigate whether the socio-economic background of the school continues to have an effect on achievement at university.

Conclusions

Our study shows that opportunity cost increases sharply at the secondary–tertiary transition across all profiles. While this is not unexpected because students are still adjusting to higher demands on their commitment and their performance at university, it is important for institutions to recognize these effects and implement measures to keep the motivation of their students high. The utility of mathematics for their professional future is a manifest source of motivation in three of the four student profiles. To maintain this source of motivation, we conclude that the high relevance of mathematics in professional applications should be stressed where possible. Utility-value-based interventions have proven to be effective (see, e.g., Soicher & Becker-Blease, 2023) and could, if integrated into first-semester courses, be a valuable resource for students in STEM fields.

Finally, institutions should pay attention to the further deterioration in self-efficacy and beliefs related to intrinsic motivation of students who hold low such beliefs about themselves upon arrival at university. Students, in particular those with maladaptive initial motivational patterns, should have ample opportunities to earn a sense of accomplishment. This would strengthen their self-efficacy, which is vital for students to persist in their degree programs.

Appendix A: Procedure of conducting latent profile analysis

Latent profile analysis is an exploratory approach; however, there is a range of indicators helping to narrow down the number of options for deciding on a model. Latent profile analysis is based on estimating model parameters using the maximum likelihood method which iteratively computes and optimizes parameter values to arrive at those values which best describe the data. *Best* in this sense means that the likelihood of the data to fit the model is maximized. To avoid arriving at a local maximum, the algorithm uses different starting values to increase the chance that the identified maximum is the global maximum of the log-likelihood function. For carrying out this procedure in *Mplus 8.8*, we chose the robust maximum likelihood estimator (Mplus syntax: `ESTIMATOR IS MLR`) and specified the number of starting values to be 500, the number of optimization steps to be 100 (`STARTS ARE 500 100`), and the number of initial stage iterations to be 50 (`STITERATIONS IS 50`). The procedure was carried out iteratively with an increasing number of profiles, starting with two profiles and going up to six profiles. Each of these steps produced several parameters indicating the goodness of model fit. In deciding on a model, we first excluded models that did not converge at a maximum or whose maximum log-likelihood value was not replicated (suggesting that the identified maximum is a local maximum and not the global maximum). We also required the entropy of the model to be at least 0.70 and each profile to contain at least 5% of the total sample. We selected the final model based on information criteria (AIC, CAIC, BIC, SABIC), with the Bayesian Information Criterion (BIC) being the most significant. The model with the lowest BIC value of all the potential models with a BIC difference less than 10 compared to the model with the next highest number of profiles was selected as the final model. The remaining information criteria were used as indicators of plausibility of this choice. This procedure was performed separately for each measurement point and resulted in a model consisting of four profiles at each measurement point, respectively.

To enable multinomial logistic regression analysis, we recoded the variable containing the school type into dichotomous variables, i.e., the seven different values of the school type variable were split into three variables which reflect whether or not (0 = no, 1 = yes) students attended an academic secondary school, a Higher Federal Technical College or a school of a type other than these two. The remaining school types were merged due to low occurrence. Since Mplus uses by default the last category (i.e., profile 4) of the categorical latent variable as the reference category, we recoded the values representing the profiles for this step into the dropped order so that we could use profile 1 as the reference category in multinomial logistic regression analysis.

Appendix B: Attrition and related descriptive statistics

Out of the 710 students participating at MP1, the 409 students who participated also at MP2 were the basis for data analysis. Table 12 provides an overview on how many students participated only at MP1 (see column "MP1") or both at MP1 and MP2 (see column "MP1 & MP2"). The results of independent *t*-tests in Table 12 show that those who participated in both waves initially had statistically significantly higher value beliefs and lower cost, and had statistically significantly better grades in their school leaving examination.

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Author contributions

Conceptualization: ME, ML, MM; methodology: ML, MM; formal analysis and investigation: ML, MM; writing—original draft preparation: MM; writing—review and editing: ME, ML; supervision: ME, ML.

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Availability of data and materials

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

Table 12 Descriptive statistics of students who participated only at MP1 or both at MP1 and MP2

	MP1	MP1 & MP2	*t*	*df*	*p*	Overall
n	301	409				788
Self-efficacy (MP1)	4.09 (1.11)	4.14 (1.01)	0.60	608.73	0.549	–
Intrinsic value (MP1)	4.05 (1.17)	4.37 (1.04)	3.81	697.00	< 0.001	–
Attainment value (MP1)	3.85 (1.11)	4.14 (1.02)	3.55	692.00	< 0.001	–
Utility value (MP1)	4.95 (1.01)	5.11 (0.87)	2.26	555.39	0.024	–
Cost (MP1)	3.20 (1.08)	2.98 (1.07)	− 2.71	695.00	0.003	–
Age	20.25 (2.78)	19.87 (2.95)	− 1.65	666.00	0.100	20.03 (2.82)
Gender (1 = male, 2 = female)	1.29 (0.45)	1.28 (0.48)	− 0.36	661.00	0.716	1.26 (0.44)
Year of graduation	2020.55 (2.58)	2020.88 (2.65)	1.60	666.00	0.111	2020.74 (2.57)
Grade in school leaving exam (1–5)	2.20 (1.06)	1.75 (0.89)	− 5.18	404.49	< 0.001	1.91 (0.97)
Prior university experience (1 = yes)	0.86 (0.35)	0.89 (0.32)	0.95	668.00	0.343	0.87 (0.33)
University experience in family (1 = yes)	0.77 (0.42)	0.75 (0.43)	− 0.62	668.00	0.536	0.76 (0.43)

Except for the row showing the number of participants ("*n*"), the values in the columns "MP1" and "MP1 & MP2" are mean values followed by standard deviations in parentheses

Declarations

Ethics approval and consent to participate
Participation in this study was voluntary and subject to informed consent of the participants.

Competing interests
The authors declare that they have no competing interests.

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Research article 4: Impact of a mathematics bridging course on the motivation and learning skills of university students

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Research article 4 examines the impact of a mathematics bridging course with specific features on the motivation of students at the beginning of STEM bachelor programs (RG3). As reported in research articles 2 and 3, the motivation of these students is challenged in many ways during their secondary-tertiary transition. Many of them do not overcome these hurdles and quit their programs. Heublein et al. (2017) have identified key factors that influence students' decisions related to dropout. These include personal challenges such as problems in performance as well as features of the students' respective programs that do not meet their needs and undermine their motivation and perseverance. Many universities implement support measures to help students overcome challenges at the secondary-tertiary transition and to reduce dropout.

This research examines a five-day bridging course for beginning students in STEM bachelor programs at the University of Vienna designed specifically to reduce gaps in mathematical knowledge, to promote well-being, and to foster learning skills. In a repeated-measures survey study, motivational beliefs related to the will and the skills to learn mathematics are assessed at the beginning and at the end of the bridging course, as well as shortly before the students' first exam several weeks into the first semester.

The outcomes which the bridging course aims to achieve are that

- students are eager to master mathematical concepts and to do well in their courses;
- students gain confidence to take on academic hurdles;
- students have an improved sense of well-being at university;
- students adopt coping, metacognitive, organizational, and peer learning strategies;
- students consolidate their mathematical competencies and close gaps; and that
- students become familiar with basic processes at university.

The course has six features which are expected to yield these outcomes. These features of the bridging course are

- a self-directed and collaborative learning approach with occasional inputs;
- individual choice of a focus topic each day;

- work in small groups with an experienced tutor;
- pre-service mathematics teachers as tutors;
- the use of well-established materials based on school curricula and designed for self-directed learning;
- active onboarding of participants.

To examine in what way the bridging course contributes to the desired outcomes, we operationalize these outcomes as aspects of the *will to learn* mathematics as well as as *skills to learn* mathematics. These aspects are considered important for the promotion of lifelong learning (Lüftenegger et al., 2012). We hypothesize that the bridging course enhances the will to learn and the skills to learn mathematics. To test these hypotheses, a pilot study was set up in 2019 followed by the main study in 2021, which featured adaptations and improvements based on learnings from the pilot. The constructs surveyed in the main study were *achievement goals*, *basic psychological needs*, *implicit theories of ability*, and *self-efficacy* as aspects of the will to learn mathematics, and *reactions to errors* and *self-regulated learning strategies* as aspects of the skills to learn mathematics. To be able to determine the impact of the bridging course, we established a case-control design by surveying both course participants (intervention group) and incoming students who did not participate in the course (control group). The questionnaire surveys reached 293 course participants and 386 students in the control group, resulting in a total of 679 respondents. Repeated-measures analysis of variance and paired-samples *t*-tests were employed to determine the development of motivational beliefs during the bridging course (short-term developments) as well as between the first participation in the questionnaire study and the time shortly before the first exam (intermediate-term developments).

The short-term results show that the aspects of the will to learn developed differently during the bridging course. In this regard, social relatedness was boosted during the bridging course, while, perhaps surprisingly, autonomy and competence decreased. The skills to learn, in turn, showed a clearly positive short-term development. The intermediate-term results are characterized, for the most part, by stable or negative developments. An exception to this is the development of social relatedness, which increased also in the intermediate term within the intervention group.

The results suggest that a mathematics bridging course with specific features aimed to positively impact the will to learn and the skills to learn mathematics can be effective in the short term and boost motivation and learning skills at a time when motivational support and guidance are particularly important for students. In the intermediate term, however, the demands and challenges of the first semester at university impact the students' motivation. Therefore, to keep motivation up in the long term, accompanying support programs throughout the first semester can help prevent the dropout of students who have the academic potential to complete their degree. Possible selection effects are discussed in the paper.

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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

Extended author information available on the last page of the article

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 ($\omega < .6$) 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.

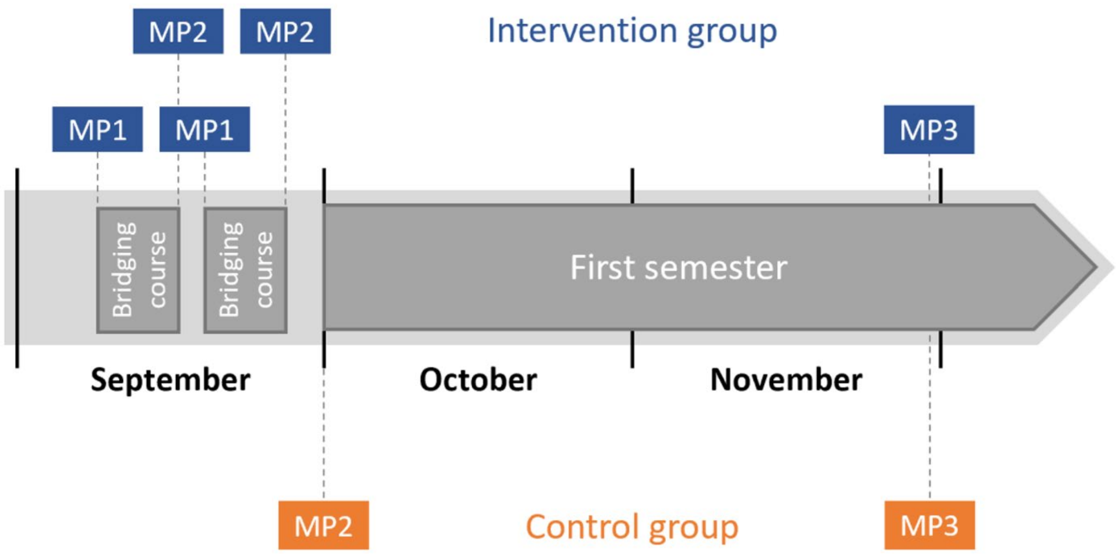

Fig. 1 Timeline of measurement points (MP) during the bridging course and the first semester in the intervention group and in the control group

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).

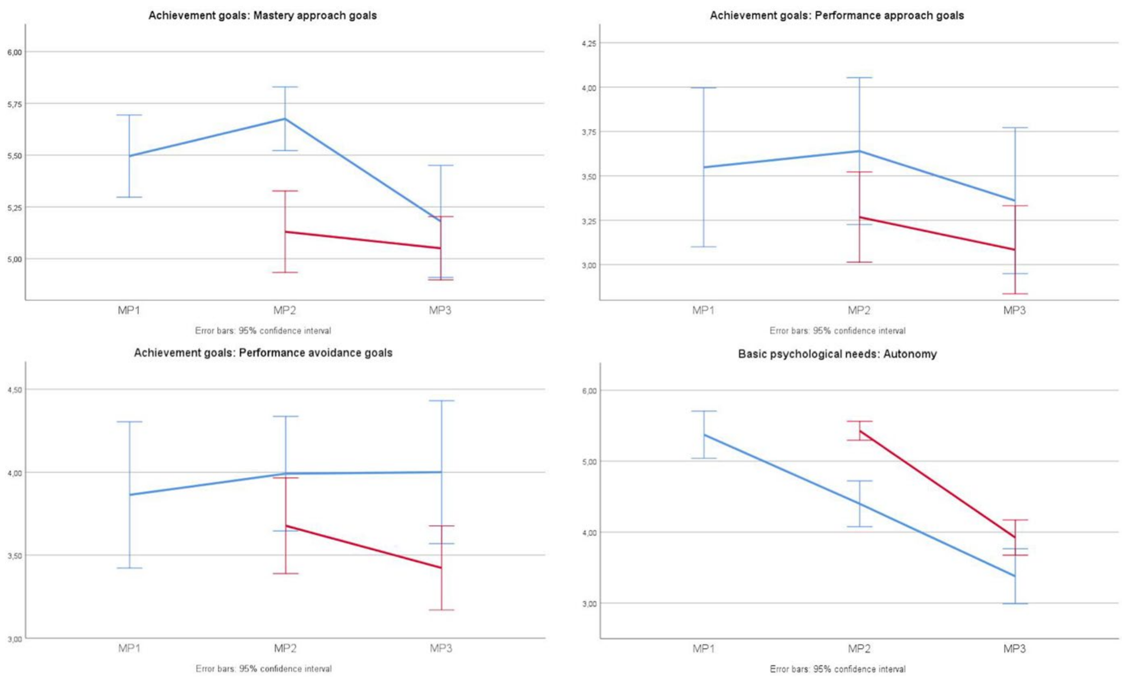

Fig. 2 Development across the measurement points (MP) of aspects of the will to learn in the intervention group (blue) and in the control group (red)

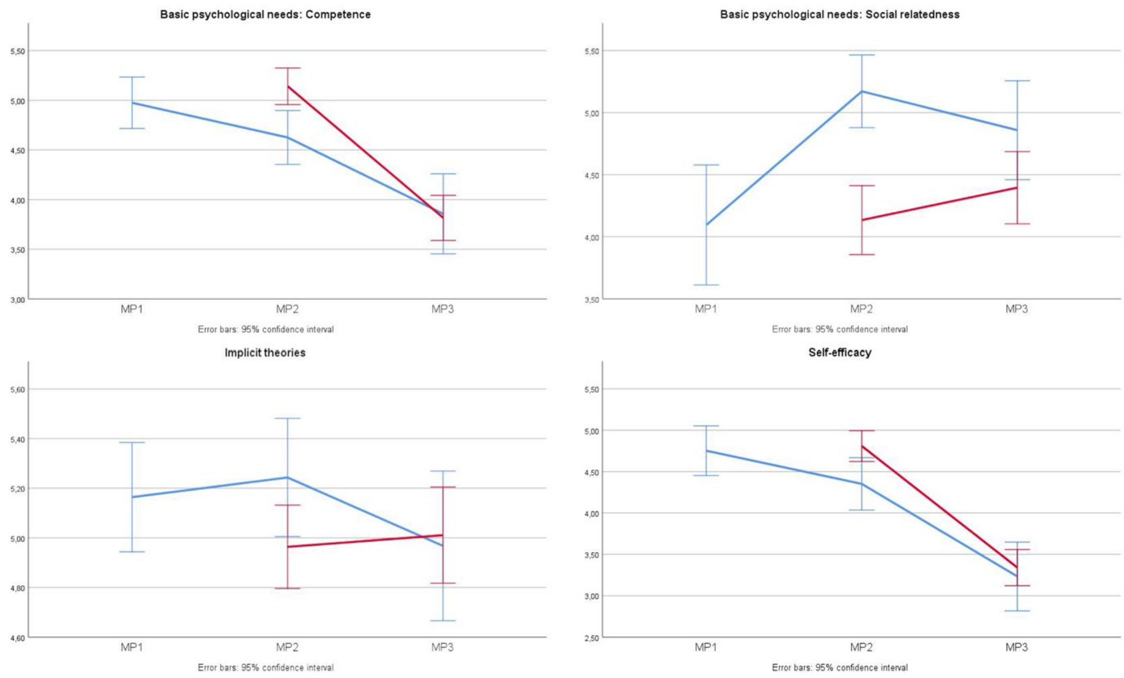

Fig. 2 (continued)

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).

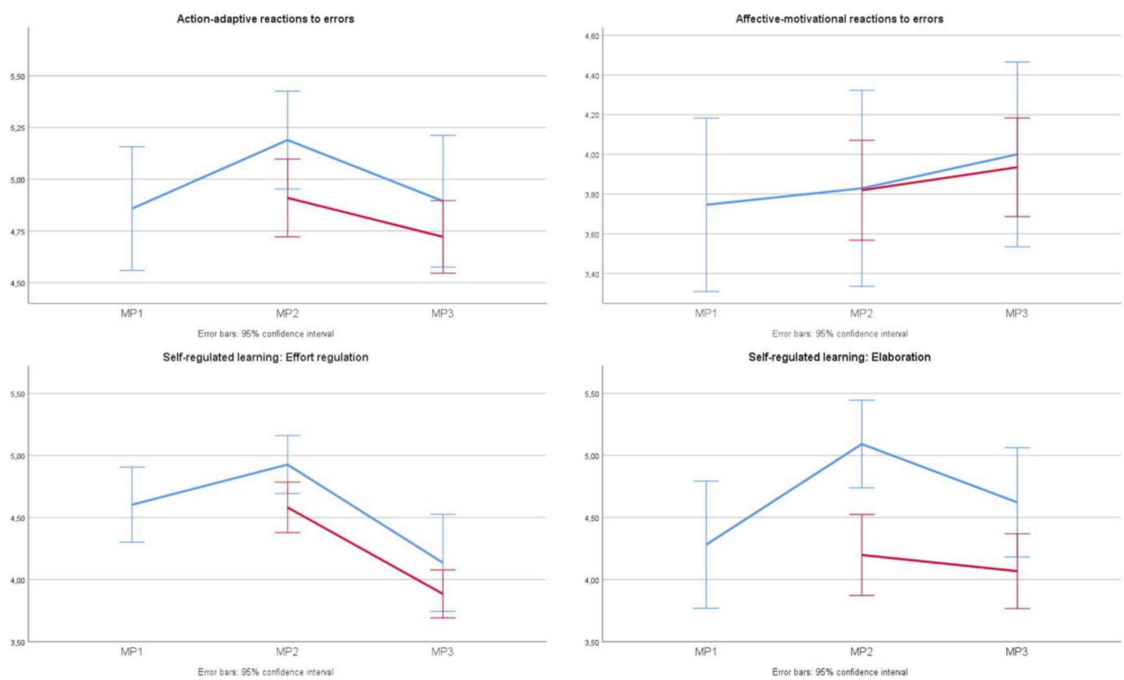

Fig. 3 Development across the measurement points (MP) of skills to learn in the intervention group (blue) and in the control group (red)

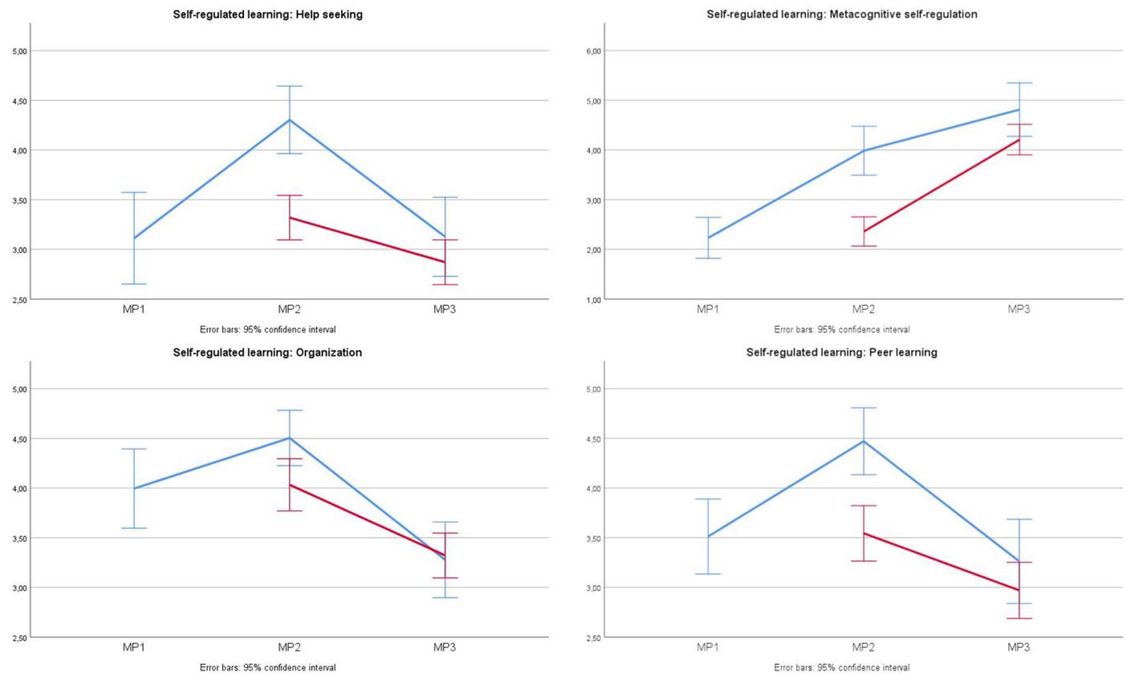

Fig. 3 (continued)

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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Declarations

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

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Discussion

This dissertation studies motivational aspects of adolescents with regard to learning mathematics. Specifically, research article 1 examines differences in the aspirations of youths to enter STEM bachelor programs by gender and age cohorts during their upper secondary education. Research articles 2, 3, and 4 investigate the development of student motivation during the transition from secondary education into STEM bachelor programs, the latter focusing on an intervention to improve motivation.

This section discusses the findings of these articles and how they contribute to the research goals of this dissertation.

Differences in STEM career intentions by gender and age cohorts in upper secondary education

To secure the availability of an innovative and internationally competitive workforce, it is crucial that youths are provided with opportunities to develop interests and goals in STEM. According to Gottfredson (1981), the development of career intentions starts early in childhood. The motivation to purposefully pursue activities in a specific area evolves during adolescence; by identifying personal abilities and interests, the range of professions youths consider as suitable for themselves becomes more concrete (Gottfredson, 1981). Findings from research article 1 indicate that the self-efficacy of youths who have already developed a basic level of motivation to learn mathematics at the beginning of upper secondary school is set to rise in the course of their further upper secondary education. In general, however, the differences in self-efficacy, outcome expectations, and goals—factors indicative of STEM career intentions—are not unidirectional and occur with small or very small effect sizes. This suggests that the STEM career intentions of students attending academic upper secondary schools are for the most part stable and consolidated in upper secondary education. While these findings are related to career *intentions*, Wong et al. (2022) have pointed out that career *decisions* may well be different from career intentions. Indeed, they found that a proportion of students abandon the STEM track due to the prospect of higher incomes in other fields. This aligns with the observed decrease in perceived utility of mathematics among a majority of beginning students reported in research article 3 and stresses the importance of showcasing the utility of mathematics throughout tertiary education. This strategy has already proven successful in high school STEM courses (Harackiewicz et al., 2012) and college psychology courses (Soicher & Becker-Blease, 2023). A better understanding of the relation between career intentions and actual career decisions gained in future research may well provide further insights into how to keep students on a STEM track.

Our examination of subgroups revealed considerable gender differences, all in favor of male students. Indeed, lower values in higher grades were mostly seen in female students, while male students showed equal or higher values in higher grades on the whole. However, the effect sizes in our study were small. This suggests that gender differences in learning mathematics, which are often rooted in childhood (Gottfredson, 1981), are retained during upper secondary education, if not reinforced. To counteract this, we recommend that schools foster a growth mindset and self-efficacy for learning mathematics. A growth mindset will reduce the tendency of ascribing ability to fixed traits such as gender (Starr & Simpkins, 2021). An increase in self-efficacy enhances learners' beliefs in their own skills and fosters their perseverance in the face of challenges (Bandura, 1995). Improving self-efficacy, in turn, requires that teachers provide plenty of opportunities for mastery experiences and present social models who provide vicarious experiences (Bandura, 1995). The social environment of learners, on the other hand, should be aware of its persuasive function—a further source of self-efficacy (Bandura, 1995)—and use it responsibly, for example when making statements about talents and suitable professions.

Development of the motivation to learn mathematics during the secondary-tertiary transition

The high dropout rates in STEM bachelor programs have prompted investigations of the major challenges youths face during the secondary-tertiary transition (e.g., Heublein et al., 2017). Research articles 2, 3 and 4 add how these challenges affect the motivation to learn mathematics of students who enter STEM bachelor programs at the University of Vienna and at the Vienna

University of Technology (TU Wien). While institutional conditions and their fit with students' needs have a significant influence on whether students transition successfully into STEM bachelor programs, research articles 2 and 4 show that motivation decreases in the course of the first semester at both institutions. The motivation reported by the students who intend to pursue a career in STEM fields and enroll in a STEM bachelor program peaks at the start of the program and then declines sharply. While the increased level of required effort and commitment at university reported by the students is accounted for by higher requirements than at school (Christie et al., 2013; Göller, 2020), the concurrent strong decline in perceived utility of mathematics as well as in intrinsic value and perceived importance of learning mathematics is consistent with observations based on stage-environment fit theory, which showed a decline in motivational constructs over time (Scherrer & Preckel, 2019). The decline in utility value, intrinsic value, and personal importance in the context of mathematics observed in our work is a contribution to the call of Scherrer and Preckel (2019) for domain-specific investigations of the development of motivation. Research articles 2 shows that gender differences in the development of motivation persist during the initial phase of STEM bachelor programs.

We contribute to the understanding of how students cope with the specific challenges of the secondary-tertiary transition in research article 3, which concludes that students with high prior achievement and initial motivation are in a good position to master this transition. By contrast, students with intermediate or low intrinsic motivation and self-efficacy are in need of additional support so they will not quit their programs in spite of their academic potential. This is in line with the findings of Geisler and Rolka (2021), who conclude that students with initially favorable beliefs are able to maintain these beliefs while initially maladaptive beliefs of students deteriorate further. Remarkably, a considerable proportion of students show a high initial level of extrinsic motivation, which, however, decreases strongly within several weeks. This suggests that students primarily motivated by the utility of learning mathematics for their prospective future careers are not able to maintain this motivation or become less driven by the prospective benefits of mathematics. Since these students also show a lower level of intrinsic motivation, they might face hurdles that lead them to contemplate leaving the STEM track.

Impact of support programs on the motivation to learn mathematics during the secondary-tertiary transition

These consistent findings raise the question of how to prevent a decrease in motivation during the secondary-tertiary transition by way of support programs. Research article 4 reports the results of a case study that shows how students' personal psychological resources to self-regulate their learning behavior may be fostered by an intervention that focuses on self-directed and collaborative learning with autonomous selection of course content. Some aspects of psychological well-being develop negatively in the course of the first semester, despite the intervention. While an intervention of this design is not able to fully address all challenges that arise at the secondary-tertiary transition, our results demonstrate its potential to promote learning strategies, which are an important precursor of successful adjustment to the academic world (van Rooij et al., 2018). An additional benefit of such interventions is that they foster connections with peers, which is crucial for the well-being of students (Deci & Ryan, 2000).

Limitations and future research

To obtain reliable longitudinal data for the two repeated-measures studies conducted as part of this dissertation, we reached out to a large number of potential participants. The challenge in such sampling is to motivate a sizable, representative part of the target group to fill in questionnaires. The students who completed all surveys were likely more motivated to pursue their studies than those who did not participate, possibly resulting in a positively biased sample. Students who quit their bachelor program early on and thus became unavailable for follow-up surveys add to this bias. Due to this range restriction, the results likely reflect the experiences of students who were on a good track to master the secondary-tertiary transition to start with, while those who dropped out early do not figure in the results in a substantial way. For this reason, the developments reported in research articles 2, 3, and 4 might be more positive than they actually were for the target group as a whole.

The four research articles of this dissertation provide insights into different stages of the educational careers of adolescents. Rather than capturing continuous individual trajectories, they give an overview of glimpses drawn from a large number of schools and two large universities. It remains a desideratum for future research to track students over a longer period of time to obtain a more complete picture of how their learning motivation develops and influences their decisions. Of course, tracking individual students over a longer period requires substantial resources and a positive attitude on part of the students to participate in research. For the specific case of the Austrian educational system, we recommend an expansion of the institutionally conducted accompanying research which, as of 2024, comprises standardized skill testing at the primary and lower secondary school level ("Informelle Kompetenzmessung PLUS – iKM^{PLUS}") as well as graduate tracking ("Absolvent:innen-Tracking – ATRACK") at universities. This would enable more accurate monitoring of the educational system and help researchers provide tailored recommendations to stakeholders in education.

Conclusion

The secondary-tertiary transition into STEM fields is a period of heightened vulnerability in the life of young adults. Their experience of this transition impacts their future educational and career choices. To master this period, students require a wide range of competencies and resources, including

– a modicum of intrinsic motivation and interest to learn mathematics;
– persistence in the face of challenges and setbacks;
– a supportive social environment;
– skills to manage changes in one's life circumstances that often accompany the transition to university;
– readiness to accept support, be it institutional or otherwise; and
– an open mind and willingness to engage in lifelong learning.

To meet these many-faceted demands and stay on track, students require guidance and support both from their schools and academic programs as well as from their social network, in particular their peers. Due to the crucial role of self-efficacy and goal setting for the competencies and resources listed above, we advocate incorporating the promotion of self-efficacy and goal setting strategies into the school curricula as a general guiding principle for the work of teachers. At the tertiary level, educational stakeholders and research institutions are mandated to plan and provide resources that support first-year students.

This dissertation has shown that tailored support programs have the potential to facilitate the onboarding of incoming bachelor students in STEM fields by establishing a sense of social relatedness. It has also demonstrated that the motivation of beginning students is particularly fragile during the initial phase of bachelor programs and that the support should neither be limited to this phase nor to that of the educational institution alone.

The successful transition will to some degree depend on the readiness of students to engage in lifelong learning, which places the responsibility back on schools and the social environment to foster such life skills. Even if the demands are high to make the transition from school to university successful, the efforts and resources invested by different stakeholders will pay off in the long term—for the self-actualization of young adults as much as for economic competitiveness and societal advancement.

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