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Empowering educators: A training for pre-service and in-service teachers on gender-sensitive STEM instruction

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Abstract

Starting early in life, children, especially girls, experience obstacles when it comes to developing interest in STEM. Although teachers face an important task in promoting girls (and boys) in STEM, they often encounter hurdles in doing so. A three-month-long training for pre- and in-service teachers in elementary education was developed to counter this phenomenon. An important training feature was teaching ideas for STEM classrooms. Teachers' evaluation of the training and teaching ideas, changes in their self-concept, and elementary students' assessment of the teaching ideas were investigated. Students rated the teaching ideas favorably, with no gender differences. Even though each idea incorporated relevant didactic features for gender-sensitive STEM instruction, the teachers rated certain ideas and contents more critically than others. Nevertheless, their assessments speak in favor of the training intervention, while also indicating gaps in teachers' professional knowledge regarding gender-sensitive didactics. Implications for the design of STEM teacher education are outlined.

Keywords: gender and STEM, elementary STEM education, pre-service teachers in elementary education, interest in STEM

INTRODUCTION

Knowledge, competencies, and reflected attitudes regarding STEM (science, technology, engineering, and mathematics) are prerequisites for successfully coping with global and societal changes in the economic and working worlds (OECD, 2020). New fields of work are emerging that require an integration of mathematics, computer science, natural sciences, and technology. STEM knowledge and competencies reach beyond academic settings and individual needs, impacting society as a whole when it comes to, e.g., health and prosperity (OECD, 2020). In contrast to its importance, studies point to the obstacles hindering the development of students' STEM competencies (Lane et al., 2022; Mazana et al., 2019), or STEM achievement being strongly dependent on children's socio-economic background and gender (Itzlinger-Brunefort, 2020). Furthermore, STEM subjects are not among the most-liked school subjects, with girls often shying away from them (Luttenberger et al., 2018); a majority of girls feel estranged from STEM subjects as early as in their formative elementary years (Luttenberger et al., 2018).

With the importance of STEM in mind, teachers are faced with the task of promoting STEM education and supporting students from their early educational years onward (Lange et al., 2022). However, educational systems in Europe face strong hurdles in fulfilling this aim. These range from a low percentage of teachers choosing STEM as their teaching subjects, general teacher shortages, and teachers' critical attitudes toward STEM (Ortiz-Revilla et al., 2023). Given this context, a training concept for pre- and in-service teachers in Austria was developed that focuses on STEM instruction

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Contribution to the literature

- A comprehensive training concept for pre- and in-service elementary school teachers to promote girls in STEM was designed; it focuses on pedagogical-didactic knowledge and STEM-related attitudes and illustrates gender-sensitive STEM didactics using good-practice examples.
- Gender-sensitive STEM teaching ideas were developed and evaluated for a target group that has been neglected in research: Elementary school students in need of support due to deficits in knowledge.
- STEM teaching examples that are geared towards promoting girls (e.g., by including female-role models) are also rated positively by boys and enhance the overall quality of learning and teaching in STEM.

in elementary education (age range six to ten). The concept aims to address potential reservations of teachers and present teaching ideas that not only convey STEM knowledge in an interesting and gender-sensitive way but also incorporate essential 21st century skills, making them appealing to both girls and boys.

Barriers to & Inequalities for STEM Students in Elementary Education

International studies on students' STEM achievements show for a majority of countries that boys outperform girls. This is most notably in the 2019 TIMSS assessment, where in two-thirds of the participating countries boys outperformed girls in mathematics (Suchań et al., 2019). There are mixed results for Austria, where the present study took place. On the positive side, in the 2019 TIMSS assessment, Austrian students in elementary education (age range six to 10 years) scored in the upper performance range in mathematics compared to the EU. However, these same students scored only in the middle range in science. STEM barriers impacted girls more than boys. For instance, in 2019, a significantly higher number of boys than girls were able to solve complex mathematical problems (Itzlinger-Bruneforth, 2020).

Gender differences are not limited to performance, but also concern personal characteristics and attitudes. They are accompanied by girls' lower academic self-concept in comparison to boys, more anxiety (especially in mathematics), lower interest in STEM, and a preponderance of gender stereotyped career aspirations (Godec et al., 2024; Luttenberger et al., 2018; Martynenko et al., 2023). A large part of these obstructive attitudes can be attributed to stereotypes about females' abilities in STEM (Bieg et al., 2015; Ertl et al., 2017). Girls internalize stereotypes about lower math abilities, regarding themselves as less gifted than boys. In assessment situations, the internalized stereotype affects the perception of task difficulty, and is related to increased strain and tension, and decreased performance (Ertl et al., 2017). Over the course of childhood and adolescence, self-depreciatory assessment, and anxiety lead to avoidance of STEM, detrimental learning behaviors, and lower performance (Else-Quest et al., 2010).

Parents also shape their children's educational values and self-assessments through their attitudes and personal background toward STEM (Eccles, 2005; Wildmon et al., 2024). Parents' beliefs do not necessarily rely on objective assessments, as they for example may maintain stereotypical evaluation patterns (Ertl et al., 2017; Rodriguez-Planas & Nollenberger, 2018). Their views of STEM in turn serve as a frame of reference, meaning that they may transfer their own STEM attitudes to their children. Mothers in particular influence their daughters' attitudes toward mathematics, self-assessments, and mathematics anxiety (Casad et al., 2015). In addition to gender, socio-economic and family-related factors influence children's developments in STEM from an early age onwards (Jones et al., 2022; Nugent, 2015). Learning to participate in STEM is a form of cultural capital developed in childhood through engagement with parents, as well as out-of-school science experiences over time (Claussen & Osborne, 2013; Ennes et al., 2023). Children's family and social contexts also differ regarding the availability of science resources, or STEM role models such as parents and other adults (Eccles, 2005; Jacobs & Bleeker, 2004; Luttenberger et al., 2018; Rodriguez-Planas & Nollenberger, 2018; Watt et al., 2019). So, children do not start school as blank slates in terms of STEM, but bring with them knowledge, experiences, and attitudes that were taught at home (Eccles, 2005). Studies furthermore point out that from elementary education onwards, students steadily lose interest in STEM fields, and cease seeing these subjects as a viable option for their future or as part of their potential success (Christidou, 2011; Potvin & Hasni, 2014). In this context, teachers face the crucial task of designing STEM instruction that not only imparts knowledge but also integrates 21st century skills, motivates students, and fosters joy in learning. Positive learning experiences form the basis for promoting children's interests and attitudes toward learning content.

Barriers to STEM for Teachers in Elementary Education

Although teachers are essential in promoting students' STEM interest and knowledge, they often are also affected by barriers to STEM. This is especially seen with elementary education teachers, who themselves are not necessarily among those exhibiting a high level of self-concept, self-efficacy, or a positive attitude toward

STEM. The profession of an elementary education teacher is mostly regarded as one in which social competences, but not STEM competences, are of crucial importance. Therefore, it is not surprising that in many countries, in-service and pre-service teachers in elementary education are largely female, often with very critical attitudes toward, gender stereotypes about (Kollmayer et al., 2018), and even high anxiety levels regarding STEM subjects like mathematics (Foley et al., 2017).

In elementary education, teachers have an especially significant influence on their students' formation of attitudes, beliefs, and feelings toward a subject or knowledge domain (Furner & Bermann, 2003). However, teachers themselves may suffer from gender stereotypes (Tiedeman, 2000, 2002). Female elementary school teachers particularly influence girls, and not always in a desired way. For example, studies on mathematics have shown that the teacher's level of math anxiety influences the achievement of the girls in their classes, as well as the girls' formation of self-efficacy and self-concept in mathematics (Beilock et al., 2010). Teachers, of course, may also have a positive influence on their students and promote positive attitudes, high degrees of motivation, and a sense of self-efficacy and self-concept (Bayanova et al., 2023). Teachers' attitudes, beliefs, and feelings are also related to their teaching style and instructional strategies, e.g., the degree to which they include challenging tasks in mathematics instruction (Thompson et al., 2022).

Teachers' beliefs, attitudes, and feelings can be altered through training and education (Foley et al., 2017). As the relationship between teachers' attitudes, beliefs, feelings, and classroom practice is dynamic, with each influencing the other (Russo et al., 2020), learning (and applying) effective and motivating teaching skills are especially important.

Role of STEM in Elementary Education in Austria

With the exception of mathematics, the current Austrian elementary education curriculum does not include other specific STEM subjects; teachers can merely integrate STEM topics into their "general studies." The purpose of this subject is to provide students with the opportunity to explore their immediate environments and acquire knowledge about the world. Students here should be supported in understanding their natural, cultural, social, and technical environments (BMBWF, 2023a).

The curriculum lists a variety of topics, which can be addressed in this subject, ranging from the cultural heritage of Austria and Europe, everyday knowledge, ethics, geography, and STEM. General studies are not specifically STEM-related, and it is mostly up to teachers to determine how much STEM content they include. In light of the role that international organizations like the OECD (2020) attribute to STEM education, STEM topics are generally underrepresented in the Austrian elementary curriculum. At the same time, the results of school achievement studies on science and mathematics point to gender inequalities in Austria on the elementary education level. Overall, these findings suggest that more attention should be paid to promoting girls (and boys) when it comes to STEM.

Development of Education & Further Training Concept "Girls, Go for MINT!" for Elementary Education Teachers

In light of the above findings, a training and further education concept and intervention "Girls, go for MINT!" ("MINT" being the German acronym for STEM) was developed for pre-service and in-service teachers in elementary education. Thus, a target group that is still underrepresented in STEM education research (Phuong et al., 2023) was addressed.

A model & recommendations for trainings on STEM education

With the SciMath-DLL professional development three-component model, Brenneman et al. (2019) developed a model for training educators in STEM. The model builds up on important didactic elements like learning about STEM content and teaching, including reflection on practice and professional development, opportunities for discussion, addressing beliefs and attitudes about STEM. With such didactic elements, teachers' skills of independent teaching, reflection on their own professional behavior, motivation, and positive attitudes should be strengthened (Way et al., 2022). Furthermore, Brenneman et al. (2019) emphasize that such training should offer the participating educators' opportunities to implement their knowledge in pedagogical practice, i.e., in the classroom.

As it is described in the next paragraph, the training intervention "Girls, go for MINT!" incorporated features that Brenneman et al. (2019) regard as important in their model. A key feature of the training intervention are so-called teaching ideas for different STEM domains. They were developed to appeal to girls (as well as boys) and were implemented by the training participants in their education practice. They incorporate didactic elements that have found to be important for gender-sensitive STEM instruction, e.g., studies have found that STEM content and instruction are more appealing to girls when their relevance for everyday life and importance for society are highlighted; when the use of social skills and cooperative learning forms are emphasized; when active engagement and interest (Häussler & Hoffmann, 1998; Wodzinski, 2009), and self-efficacy are promoted, e.g., by hands-on tasks in which the children experience the outcomes of their actions (Inan & Inan, 2015; Lange et al., 2022).

According to Wodzinski (2009), even though such characteristics are important to address girls in STEM, they do not impair boys' learning. Additionally, in each teaching idea a connection between learning contents and specific professions is drawn and female role models who have made special achievements in the corresponding field are presented (see González-Pérez, 2020 on importance of role models).

Description of training & further education concept

The training "Girls, go for MINT!" encompasses three parts with different learning opportunities for the participants:

(1) introductory learning sequences on gender-sensitive teaching, motivation and interest, and the role of stereotypes for children's learning and development,

(2) teaching ideas for the STEM elementary education classroom, and

(3) opportunities for the participants to reflect upon their roles and responsibilities in teaching elementary school children, while reflecting on their own attitudes, beliefs, and emotions concerning STEM.

The teaching ideas incorporate the didactic features described above. Additionally, in each teaching idea, female role models are presented. Teaching ideas pertaining to four different STEM fields were developed, and all of them fit well into elementary level curricula from grades one to four (BMBWF, 2023a):

1. **Science–Human body & skeleton:** The teaching idea relates to the human body, in particular the skeletal system and organs. Illustrative materials including an anatomic model, skeleton, and use of a stethoscope support exploratory activities. The development of scientific thinking, methods of scientific work and exploration, and the examination of the relationship between humans and nature are the focus of the embedded tasks.
2. **Technology–Building, constructing, & chain reactions:** The teaching idea for technology deals with forces in everyday life, and how these can be integrated into a chain reaction. Competency areas of the elementary-level curriculum such as building and constructing, exploring technology, and the practical use of technology products are addressed. In addition, analytical thinking and understanding of technical principles, functions and operations are included, which can also be found in the field of computer science and mathematics.
3. **Computer science–Coding:** This teaching idea incorporates unplugged programming activities, where children learn coding concepts without using a device, as well as learning with robot devices such as Bee-Bots. Children learn analytical thinking, an understanding of technical principles, and functional and operating methods (Sun et al., 2021). The topic of coding was chosen because it is central to many STEM activities and professions. The concept of STEM explicitly includes mathematics, computer science, natural sciences, and technology, making it obvious to develop a teaching idea for computer science.
4. **Mathematics–Measures & sizes:** Measures and sizes are illustrated in tasks for measuring the human body. Concepts of size and measures are used throughout our experiences in and outside of school and are fundamental to understanding formal science processes and concepts. The principle of measuring and comparing sizes is an essential basic mathematical skill that plays an important role in everyday life in particular, as well as in the entire field of science and technology. Conceptualizing size and quantity has a developmental progression that is likely affected by multiple cognitive components (Jones et al., 2011).

The learning ideas reflected the interdisciplinary and integrated nature of STEM, e.g., by overlapping subject areas or integrating concepts that are fundamental to all STEM fields (for integration of STEM-fields in instruction, see also Seebut et al., 2023; Zhang & Zhu, 2023). Each teaching idea was designed to take up approximately three hours (180 minutes), while allowing teachers large degrees of freedom regarding the time frame, materials, and general design instruction.

Research Questions

The present study aims at an evaluation of the developed education and further training program regarding assessments by teachers and their elementary education students. The following research questions are investigated:

1. **Pre-service teachers:** Do the pre-service teachers prefer specific teaching ideas over others with regard to overall pedagogical quality and gender-sensitive instruction? To which degree do the pre-service teachers evaluate the teaching ideas positively or negatively regarding quality and gender-sensitive instruction? Does the training intervention change participants' academic self-concept in STEM?
2. **Elementary education students:** Do girls and boys differ in their assessments of learning with the teaching ideas? To which degree do elementary education students evaluate teaching ideas and learning with them positively or negatively?

Table 1. Time schedule, contents, aim, & set-up of the training

Point in time	Set-up	Aim	Contents/explanations
t1 (middle of June 2022)	Online synchronous videoconference	Opening session & introduction	General overview by course instructors & participants were introduced to each other
t2 (middle of June to begin of August 2022)	Asynchronous online units	Self-regulated learning in Moodle with text, recorded lectures, & interactive tasks	Topics: gender-sensitive didactics, motivation/interest in STEM, career orientation STEM, discussions, & reflections on pedagogical practice
t3 (optionally July or August 2022)	Two-day workshop, face-to-face, & seminar room	Learning how to implement teaching ideas & materials	Topics: teaching ideas for science, technology, engineering, & mathematics for elementary students
t4 (29th of August to 9th of September 2022)	Teaching of elementary students in school	Summer school	Every pre-service teacher had selected up to two teaching ideas, which she taught in two weeks in summer school to a group of elementary school children
t5 (middle of September 2022)	Online synchronous videoconference	Closing event	Pre-service teachers & course instructors shared teaching experiences

METHODS, SAMPLES, & VARIABLES

Sample of Pre-Service Teachers, Time Schedule, & Variables

The training and further education program "Girls, go for MINT!" was implemented at a university college of teacher education in Austria within a larger preparatory course for 34 pre-service teachers who had registered voluntarily for teaching in the "summer school 2022" program. Summer school in Austria works with students of elementary as well as secondary education who require targeted support. Summer school was introduced as a nationwide educational program by the Austrian Ministry of Education in 2021. It is always held in the last two weeks of summer vacation and aims to reduce students' deficits from the previous school year and prepare for coming one (BMBWF, 2023b).

Only the sample of female teachers (n=32) was investigated. At the start of the training program, 31 of them were bachelor students, with one pursuing a master's degree. Their degrees required them to select a specialized subject at the start of their studies even though they later can teach all main subjects in elementary education. Ten women (30.30%) had chosen language didactics; eight (24.24%) a subject focusing on fostering specific needs; five (15.15%) sports and health; five (15.15%) children's needs in the school entrance phase; four (12.12%) STEM; and two (6.06%) media didactics. Six (18.75%) teachers had taught at a school part-time, while 26 (81.25%) had gathered didactic experiences as part of school internships (one missing). None of the volunteering teachers dropped out of the training or summer school.

Each pre-service teacher was assigned to a specific school by the school authority of that respective federal state in Austria. Altogether, the pre-service teachers taught summer school at 27 different schools (some participants taught at the same school).

The training intervention "Girls, go for MINT!" was implemented as blended learning, including a Moodle learning environment, Webex videoconferencing, and in-person learning. **Table 1** shows time schedule, contents, aims, and set-up of the training.

The following variables were recorded:

1. Demographic variables including gender, age, specialization subject, bachelor, or master, etc. were recorded during t1.
2. Social academic self-concept was measured by two items from the social scale of the academic self-concept scales, SASK (Dickhäuser et al., 2002) at t1 and t5. Students rated their own abilities in STEM compared to other students on a seven-point Likert scale (example: "in comparison to my fellow students I think I am more talented/less talented in STEM"; the scale ranged from one, indicating a low, to seven, indicating a high self-concept). Assessments were taken at t1 and t5. Reliability values for the two items were Cronbach's α=.727 at t1 and α=.873 at t2 and Guttman's λ_4=.727 at t1 and λ_4=.873 at t5 (Guttman's λ_4, see Paechter et al., 2013).
3. Teaching ideas were assessed after their introduction during t3 by four items measuring whether an idea fits well to the participants' pedagogical practice, whether it is especially suitable for presenting female role models and for promoting girls' interests, and whether children find the teaching idea interesting. Items were answered on a six-point-Likert scale ranging from one indicating a negative, to six indicating a positive assessment. Reliability values were calculated for each teaching idea: science α=.556, λ_4=.640; technology α=.785, λ_4=.832; computer science α=.863, λ_4=.901; mathematics α=.806, λ_4=.894.

Table 2. Descriptive statistics for pre-service teachers' evaluations of teaching ideas after introduction at in-person workshops (for all assessments n=32)

Items	Science: Human body & skeleton (1)				Technology: Building, constructing, & chain reaction (2)				Computer science: Coding (3)				Mathematics: Measures & sizes (4)			
	M	SD	Min	Max	M	SD	Min	Max	M	SD	Min	Max	M	SD	Min	Max
... is suitable for my own pedagogical practice.	5.16	0.921	2	6	5.16	1.019	1	6	4.50	1.704	1	6	5.50	0.916	1	6
… is suitable for presenting female role models in STEM.	4.87	1.262	1	6	4.34	1.450	1	6	3.91	1.594	1	6	3.81	1.891	1	6
… is especially suitable to promote girls' interest.	3.91	1.510	1	6	3.59	1.521	1	6	3.41	1.757	1	6	3.19	1.749	1	6
Children find (topic) interesting.	5.67	0.619	4	6	5.38	0.871	1	6	4.94	1.413	1	6	5.31	0.859	1	6

Note. M: Mean & SD: Standard deviation

Table 3. Results of one-sample t-tests for each item & significance levels for MANOVA post-hoc comparisons

Item	Science (1)	Technology (2)	Computer science (3)	Mathematics (4)	MANOVA post-hoc comparisons
(Name of topic)	t, df, Sig., & Cohen's d	t, df, Sig., & Cohen's d	t, df, Sig., & Cohen's d	t, df, Sig., & Cohen's d	Result of comparison & p-value
... is suitable for my own pedagogical practice.	10.600, 31*, & d=1.874	9.190, 31*, & d=1.625	3.320, 31*, & d=0.587	12.354, 31*, & d=2.184	1>3 (p≤.05), 2>3 (p≤.05), & 4>3 (p≤.01)
… is suitable for presenting female role models in STEM.	6.420, 31*, & d=1.135	3.291, 31*, & d=0.582	1.442, 31, n .s., & d=0.255	0.935, 31, n. s., & d=0.165	1>4 (p≤.001) & 1>3 (p≤.001)
… is especially suitable to promote girls' interest.	1.378, 31, n. s., & d=0.244	0.682, 31, n. s., & d=0.121	-0.521, 31, n. s., & d=-0.092	-1.01, 31, n. s., & d=-0.179	1>4 (p≤.001) & 1>3 (p≤.001)
Children find (topic) interesting.	18.851, 31*, & d=3.332	12.182, 31*, & d=3.332	5.756, 31*, & d=0.993	11.936, 31*, & d=2.110	Factor was not significant; no post-hoc tests conducted

Note. For all assessments n=32; *p≤.0125 (significance level according to Bonferroni correction); results of MANOVA post-hoc comparisons: Numbers indicate respective teaching idea; & a relation of > describes whether one idea was favored over another one

Sample of Students in Elementary Education & Variables

The pre-service teachers conducted the teaching ideas with 330 summer school children (164 girls and 166 boys) in grade 1 to grade 4 (the children's grade in the previous school year). Each child experienced one or two of the teaching ideas.

After learning with an idea, children used three items to assess the degree to which they experienced joy in learning and found learning exciting, plus the degree to which their summer school class had enjoyed learning. Items were formulated in such a way that they always referred to the specific content, e.g., "I had fun measuring my own and my classmates' bodies" or "my class liked the chain reactions".

All items were answered on a five-point Likert scale ranging from one (negative assessment) to five (positive assessment). To support the children, scale values were also expressed using smiley symbols and, if necessary, items were read to them.

Reliability values were calculated for each teaching idea: science a=.720, λ_4=.536; technology a=.766, λ_4=.548; computer science a=.676, λ_4=.609; mathematics a=.639, λ_4=.536.

RESULTS

Pre-Service Teachers

Evaluation of teaching ideas

Two research questions were investigated: whether the pre-service teachers preferred specific ideas over others, and the degree to which they positively (or negatively) evaluated an idea. **Table 2** shows the descriptive statistics for the assessments of the teaching ideas. Differences between assessments of the teaching ideas were evaluated with a repeated measures multivariate analysis of variance (MANOVA, Wilks-Lambda F[12, 20]=2.290; p≤.05, η^2=.579). Evaluations differed significantly for the first three items (suitability for pedagogical practice: Greenhouse-Geisser F[2.301, 93]=5.324, p≤.01, η^2=.147; role models: F[2.668, 93]=6.513, p≤.001, η^2=.174; girls' interest: F[2.705, 93]=3.309, p≤.05, η^2=.096). Pair-wise comparisons and the direction of differences between the teaching ideas are shown in **Table 3**. Only a statistical tendency was found for the assessment of children's overall interest; Greenhouse-Geisser F-value was employed due to lack of sphericity, F[2.334, 93]=2.747, p=.063, η^2=.081.

Table 4. Pre-service teachers' academic self-concept at start & end of training intervention

	t1 (opening session)				t5 (end of training)			
In comparison to my fellow students …	M	SD	Min	Max	M	SD	Min	Max
I am in STEM (1=less talented to 7=more talented).	3.59	1.241	1	6	4.03	.967	1	6
I am in STEM (1=less to 7=more intelligent).	3.75	1.218	1	6	4.03	1.031	1	6

Note. For all assessments n=32; M: Mean; & SD: Standard deviation

Furthermore, the degree to which pre-service teachers positively or negatively assessed the teaching ideas was investigated. For each item assessing a specific teaching idea, a one-way t-test with Bonferroni adjustments was carried out to investigate whether the mean value of teachers' evaluation deviates significantly from the mean of the scale (α-level of .0125 in the case of four items; examples for methodology, e.g., in Paechter & Maier, 2010; Taleb et al., 2017). The respective t-values are shown in **Table 3**. For the items on suitability of the teaching idea for pedagogical practice and on promotion of children's interest, the pre-service teachers' assessments deviated significantly from the mean, speaking in favor of positive evaluations. Concerning the assessment whether a teaching idea is suitable for presenting female role models for STEM, a significant value was found only for the teaching ideas on science and technology; they were favorably evaluated. Concerning the assessment whether a teaching idea is especially suitable for promoting girls' interests, no significances were found, i.e., all teaching ideas were evaluated by values lying in the middle of the scale (neither favorable nor unfavorable evaluations).

Pre-service teachers' changes in self-concept

It was investigated whether participants' academic self-concept in STEM would change over the course of the training. **Table 4** shows the descriptive statistics for pre-service teachers' assessments of their social academic self-concept at the start and end of the training intervention. MANOVA suggests a positive change in the self-concept (Wilks-Lambda $F[2, 30]=3.410$; $p \leq .05$, $\eta^2=.185$) between the two points in time. However, only the difference for the first item was significant (first item: $F[1, 31]=5.957$, $p \leq .05$, $\eta^2=.161$; second item: $F[1, 31]=2.417$, $p=.130$, $\eta^2=.072$).

Students in Elementary Education

It was investigated whether girls and boys differ in their evaluations of the teaching ideas.

In a first step, ANOVAs considering the hierarchical structure of the sample (i.e., that individual children are nested within summer school groups) were conducted to test for differences between female and male students (SPSS MIXED procedure with fixed factor gender; Field, 2018). Random intercepts and random slopes were added to ANOVAs. Random intercept models allow the mean values between groups to differ; they consider that intercepts may vary across groups. Random slope models allow each group to have a different relation between independent and dependent variables; they consider that slopes may vary across groups. Both the random intercept and the random slope model were tested against the baseline model that did not account for the multi-level structure. The random intercept model did perform significantly better than the baseline model in seven of 12 cases ($4.80 \leq \chi^2[1] \leq 18.18$) and the random slope model did perform significantly better than the baseline model in three of 12 cases ($13.45 \leq \chi^2[1] \leq 14.36$). However, neither the variance of the intercepts nor the variance of the slopes was significantly different from zero in any of the 12 cases. With no significant difference between intercepts and between slopes, MANOVA with no accounting for the multi-level structure can be conducted and used for interpretation. This has also the benefit that alpha inflation is not an issue. Hence, a MANOVA was conducted for the three assessments for each teaching idea to test for differences between girls and boys.

MANOVA results reject the assumption of gender differences for all four teaching ideas (science: $F[3, 162]=0.395$, $p=.813$, $\eta^2=.023$; technology: $F[3, 40]=0.317$, $p=.813$, $\eta^2=.023$; computer science: $F[3, 76]=1.269$, $p=.291$, $\eta^2=.048$; mathematics: $F[3, 86]=0.389$, $p=.767$, $\eta^2=.013$). **Table 5** shows the students' evaluations of the teaching ideas with values for the whole sample as well as for girls and boys separately.

Furthermore, the degree to which children positively or negatively assess the teaching ideas was investigated. One-way t-tests with Bonferroni adjustments were carried out for each idea and item (a-level of .167 for three items). These investigated the assumption that the mean value of students' evaluations deviates significantly from the mean of the scale. The respective t-values are shown in **Table 5**. As all p-values were below $p \leq .001$, all tests were significant.

DISCUSSION

Pre-Service Teachers' Evaluations & Preferences

Evaluation of teaching ideas regarding overall pedagogical quality

The pre-service teachers assessed the suitability of the teaching ideas for the teachers' pedagogical practice and their potential to promote children's interest. It was investigated whether specific teaching ideas were

Table 5. Elementary education students' assessments of teaching ideas

Topic	Whole sample					t, df*, & Cohen's d	Girls					Boys				
	n	M	SD	Min	Max		n	M	SD	Min	Max	n	M	SD	Min	Max
Science (1)																
Had fun	169	4.49	.749	1	5	25.882, 168, & d=1.991	83	4.53	.687	1	5	83	4.45	.815	1	5
Found it exciting	170	4.23	.942	1	5	17.012, 169, & d=1.305	84	4.30	.818	1	5	83	4.16	1.065	1	5
My class liked …	173	4.46	.859	1	5	22.382, 172, & d=1.702	87	4.52	.776	1	5	83	4.42	.912	1	5
Technology (2)																
Had fun	44	4.27	.949	2	5	8.896, 43, & d=1.341	20	4.25	.967	2	5	24	4.29	.955	2	5
Found it exciting	44	4.02	1.151	2	5	5.893, 43, & d=0.888	20	3.90	1.252	2	5	24	4.13	1.076	2	5
My class liked …	44	4.36	1.059	1	5	8.545, 43, & d=1.288	20	4.25	1.251	1	5	24	4.46	.884	2	5
Computer science (3)																
Had fun	85	4.40	.876	2	5	14.741, 84, & d=1.599	39	4.26	1.044	2	5	42	4.50	.707	3	5
Found it exciting	85	4.00	1.134	1	5	8.131, 84, & d=0.882	39	3.87	1.196	1	5	43	4.09	1.087	1	5
My class liked …	85	4.24	1.087	1	5	10.475, 84, & d=1.136	38	4.26	.978	1	5	43	4.16	1.214	1	5
Mathematics (4)																
Had fun	92	4.21	1.075	1	5	10.770, 91, & d=1.123	44	4.23	1.008	1	5	47	4.17	1.148	1	5
Found it exciting	92	4.04	1.078	1	5	9.281, 91, & d=0.968	44	4.14	1.047	1	5	47	3.94	1.111	1	5
My class liked …	92	4.27	1.159	1	5	10.526, 91, & d=1.097	45	4.24	1.246	1	5	45	4.30	1.093	1	5

Note. **t*-value & degrees of freedom for test against mean of scale=3; all *p*-values below $p \leq .0167$ (significance level according to Bonferroni correction); M: Mean; & SD: Standard deviation

assessed more positively or negatively than others. Hardly any differences were found in the assessments.

Only regarding the suitability of the teaching ideas for teachers' pedagogical practice did the teaching idea for coding (computer science) receive a more critical assessment. However, despite these (smaller) differences, all teaching ideas received very positive evaluations (significantly higher than the scale mean of 3.50), with means ranging between 4.50 and 5.50 on a six-point Likert scale.

Evaluation of teaching ideas regarding gender-sensitive instruction

The pre-service teachers assessed the capacity of the teaching ideas (and thus of the didactic concept) to raise girls' interest, as well as their suitability to present female role models in STEM. The teaching idea for science was regarded as the most suitable to boost girls' interest and present female role models; it received better evaluations than the ideas for mathematics (measuring) and coding. Although both the idea for science and the one for mathematics tie into the "human body" topic, the former was rated more positively. This result is all the more interesting, as both ideas include features of gender-sensitive didactics. A possible explanation for this could be that for the teachers, the science teaching idea was strongly associated with the domains of biology and medicine. These belong to natural science domains that are less frequently seen as "typically male" and have a high proportion of women in the respective professional domains and vocational programs (Ertl et al., 2017). Studies furthermore point out that teachers of young children (in many countries almost exclusively women) are not equally receptive to all STEM fields. This was also evident in a study by Pendergast et al. (2017) in which the female teachers preferred topics in life science over earth science or physical science. Pendergast et al. (2017), but did not specifically investigate gender-sensitivity of instruction.

The teaching ideas were evaluated more critically regarding the features of gender-sensitive instruction. For all teaching ideas, the assessments of their suitability to especially promote girls' interests were only in the middle of the scale. Concerning their suitability to present female role models in STEM, only the ideas for science and technology received evaluations above the scale mean. This result is even more interesting, as all teaching ideas include characteristics that, according to research, are important and suitable for appealing to girls: linking STEM content to application and everyday-life topics, immediate sense of accomplishment through hands-on experiences, opportunities for social interactions and collective engagement, gender-neutral language, incorporation of female role models, etc. (Häussler & Hoffmann, 1998; Stephenson et al., 2022; Wodzinski, 2009). Furthermore, the teachers' assessments did not mirror the girls' assessment. They evaluated all ideas very favorably, also those, which according to the teachers were less suitable for gender-sensitive instruction.

These results raise the question of whether teachers recognized that the design features used are important for promoting girls in STEM, and which features they perceive as important. They also emphasize the need for addressing issues of gender-sensitive STEM education in teacher education, as well as the requirement for more research on pre-service teachers' conceptions of gender-sensitive instruction.

Pre-service teachers' changes in academic self-concept

In the study the pre-service teachers' social self-concept concerning teaching in STEM was measured at the beginning and at the end of the training. Studies of teacher training in STEM emphasize that it is important to address not only subject matter and pedagogical knowledge, but also subjective job-related attitudes such as self-concept in training. These are factors that are also important for enjoyment and satisfaction in a teaching profession (Brenneman et al., 2019; Lange et al., 2022). Bagiati and Evangelou (2015) emphasize the importance of confidence in professional skills due to experiences as a facilitator for teachers to introduce technical learning contents in the classroom for young children.

STEM research has shown that elementary education teachers in particular (predominantly women) tend to have a more critical self-concept in STEM and often shy away from STEM (Kollmayer et al., 2018). These results fit the present study in which only a few of the pre-service teachers had chosen STEM as a special subject. Given this, it is of importance that the female teachers were able to develop a more positive self-concept in STEM during the training from the beginning to the end of the nearly three-month training program. During their training, they received ample opportunities to learn more about teaching in STEM, both in general and with a specific focus on girls. They also had the opportunity to apply their new knowledge and skills directly in the summer school classroom. In this regard, the training displayed success that went beyond cognitive learning goals, while also affecting attitudes.

Elementary Education Students' Evaluations

Two questions were investigated: whether the teaching ideas were attractive for the children, and whether they were appealing to both girls and boys. Possible reservations by the pre-service teachers concerning the teaching ideas' potential to appeal to girls could not be confirmed. No differences between girls' and boys' evaluations could be found. This aspect is even more interesting and important in light of how the ideas specifically incorporated female role models.

Altogether, the results speak for the didactic measures taken to increase the appeal of STEM education for both girls and boys (didactic measures that are recommended for gender-sensitive instruction, see Dierickx et al., 2022; Stephenson et al., 2022). As learning with teaching ideas was positively evaluated by both, boys and girls, the measures seem to have been appealing to both genders. The inclusion of the above didactic measures would also be supported by research on gender-sensitive STEM instruction, e.g., Wodzinski (2009, p. 583 on gender-sensitive didactics in physics) has pointed out that "*orientation of teaching towards girls also benefits boys and improves the quality of … teaching*" and "*if the lessons are directed towards the girls, it is also right for boys …*"

Limitations

This study is not without limitations. For future research it would be desirable to include a control group for measuring the temporal development of the teachers' academic self-concept. Also, teachers' and children's assessments could have been influenced by the novelty of the teaching approach or by social desirability. The results do not allow the identification of specific didactic characteristics appealing to girls. It can merely be concluded that the array of different didactic characteristics in each teaching idea was important for the promotion of girls' (and boys') interests and learning.

CONCLUSIONS & PRACTICAL IMPLICATIONS

The study was targeted at an important but still under-researched group in STEM, which according to Phuong et al. (2023) is in need of support and more research: elementary education students and their teachers. International achievement tests like TIMSS identify challenges for the development of STEM competencies in this cohort of students, with girls being particularly impacted (Itzlinger-Bruneforth, 2020). In response, an education and further training concept was designed, implemented, and evaluated. Teachers gained not only knowledge and professional skills over the course of the training, but also developed a higher, more confident self-concept (Lange et al., 2022). Although the training content received overall positive evaluations, instructors exhibited preferences for certain topics, assuming similar preferences among their students. However, these presumptions were not consistently accurate. Particularly concerning gender disparities, educators tended to underestimate girls' levels of motivation and interest.

The following implications and recommendations for teacher training and design of teaching ideas emerge from this research.

1. **Addressing professional skills and attitudes in STEM teacher training:** While educators are faced with the crucial yet challenging task of supporting children in STEM, they themselves encounter obstacles within the field (Foley et al., 2017; Kollmayer et al., 2018). However, children's advancement in STEM is not solely influenced by teachers' expertise; their attitudes also play a pivotal role (Feierabend et al., 2024; Lange et al., 2022). Hence, our training intervention effectively targeted both professional skills and the STEM self-concept of pre-service teachers.
2. **Explicitly addressing equity issues in STEM teacher education:** Since pre-service teachers are susceptible to gender-stereotyped attitudes, it is advisable to openly discuss and reflect on equity matters during training sessions (Archer et al., 2022; Chowdhuri et al., 2023). Our intervention incorporated this approach in different ways, particularly in theory-based modules, reflection sessions, and through the integration of good-practice examples.
3. **Implementing good-practice teaching ideas in the training materials:** The above arguments also speak in favor of incorporating good-practice examples that provide educators with practical guidance.
4. **Application of gender-sensitive didactic elements in STEM:** The teaching ideas developed in our intervention embraced gender-sensitive practices, including featuring female role models, facilitating hands-on experiences (Stephenson et al., 2022), and referencing the everyday lives of both girls and boys (Dierickx et al., 2022). The results indicate that the teaching ideas could engage the interests of both genders.
5. **Need for evaluation by students:** Teachers cannot always accurately assess the abilities and preferences of their students (Rebmann et al., 2015; Seidel et al., 2021). This is also evident in our study in the comparison of the pre-service teachers' assessments of the teaching ideas' gender fairness and the actual assessments of the female and male students.
6. **Implementation of STEM already in elementary education:** Internationally, education systems vary in when STEM subjects are introduced. As described, science, technology and engineering are not systematically introduced in elementary education in Austria. The present study shows that this is indeed possible and that these subjects arouse pupils' interest.

Altogether, the results speak in favor of the training intervention, especially concerning the teaching ideas. The teachers learned about good-practice examples for STEM instruction, which they mainly evaluated positively. The intervention was accompanied by changes in the teachers' academic self-concept. However, the results point out gaps in knowledge about teachers' attitudes, their professional knowledge about gender-sensitive didactics, and further needs for teacher training. Another important result concerns the instructional design of the STEM teaching ideas; they speak for didactic characteristics like the ones implemented in the teaching ideas and offer ideas for designing instruction in the STEM classroom.

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