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Research paper

Challenges of a Gender-Sensitive Intervention Study Using Image-Generating AI to Increase STEM Career Aspirations

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ABSTRACT

There is an international shortage of skilled workers in the STEM field. Therefore, it is also recommended that out-of-school learning places be incorporated into STEM education. Nevertheless, there is a research gap regarding their suitability for promoting STEM career aspirations. To close this gap, an intervention that promotes STEM career aspirations is needed. In this study, a revised version of such an intervention approach is evaluated at an out-of-school student lab. A particular attempt was made to diversify STEM stereotypes, for example, through videos with AI content, thereby contributing to a reduction in perceived masculine defaults. It was assumed that the intervention would improve career-related STEM self-efficacy beliefs, career-related STEM outcome expectations, individual STEM interest, and STEM career aspirations, regardless of gender, but even greater among students who identify with the female gender role. Furthermore, an increased situational interest in the intervention content among those students was assumed. This could not be confirmed, as students identified as female or male. The only significant results were a decline in STEM interest among female students and not among male students, as well as lower self-efficacy beliefs among female students, regardless of testing time. The intervention should be further revised and evaluated. In particular, it is important to draw the students' attention to the videos more extensively, to create identification potential through an AI avatar, to focus the task formats more on cooperative work, and to reduce their scope and complexity. An instrument for assessing STEM stereotypes should also be incorporated.

Keywords: stereotypes, AI, STEM, career guidance, out-of-school, student lab

In 2026, there were 369,400 vacancies in STEM occupations in Germany (Anger et al., 2026). At the European level, the European Commission also anticipates a shortage of skilled graduates in STEM fields in some areas, citing information and communication technology (ICT) as an example (European Commission, 2025). This shortage matters because the ICT and engineering sectors in particular are crucial to achieving digital and green transitions (European Commission, 2025). Overall, improved STEM education should also help close the skills gap described above (Anger et al., 2026; European Commission, 2025).

To combat this shortage, the National STEM Forum recommends, among other things, integrating out-of-school STEM learning opportunities to specifically promote interest in STEM and advertise STEM careers (Nationales MINT Forum, 2021). However, in a systematic literature review, Romanik and Wegner (2025a) note that there is a research gap regarding the extent to which leaving the school learning environment, which is associated with various challenges (Sauerborn & Brühne, 2020), promotes STEM career aspirations more strongly

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than staying in school. Accordingly, a comparative study is needed to assess the suitability of out-of-school learning places for promoting STEM career aspirations, integrated into the design-based research (DBR) approach, in which an intervention suitable for this promotion should first be designed and piloted (Romanik & Wegner, 2025a). Social cognitive career theory (SCCT) highlights that career aspirations are influenced, among other things, by career-relevant interests, outcome expectations, and self-efficacy expectations (Lent, 2020). Stereotypes also play an important role in this context (Luo et al., 2021; Van Tuijl & Van Der Molen, 2016). Accordingly, an intervention aimed at increasing aspirations for STEM careers should specifically target these constructs.

The present study pursues the outlined research approach and examines a second, revised version of an intervention already designed and evaluated by Romanik and Wegner (2025b) and Romanik et al. (in press). In particular, the question is to whether the revised version of the intervention, which, among other things, uses image-generating artificial intelligence (AI) to diversify STEM stereotypes, positively influence the identified constructs. To address these research questions, the study first presents relevant approaches to interventions that increase STEM career aspirations, describes the revised intervention, and presents and discusses its effects on a sample of students at an out-of-school student lab. Further conclusions and needs relevant to practice and research are derived.

THEORETICAL BACKGROUND

To understand how educational opportunities for children can help close the skills gap in STEM fields, we should examine the theoretical mechanisms involved in the formation of career aspirations. One theory that contributes to understanding career development in different groups and has broad applicability in interventions is SCCT (Damodar et al., 2024).

The SCCT, according to Lent and Brown (1994), is a framework that is based in particular on Bandura's (1986) social cognitive theory. Over the years, SCCT has expanded to include models of interest development, making choices, persistence and performance, well-being and satisfaction, as well as self-management in career and educational contexts (Lent & Brown, 2019). When designing an intervention that promotes career aspirations among students, the SCCT's interest and decision-making models are particularly relevant for identifying influences on career aspirations. According to Lent and Brown (2019), the interest model essentially states that self-efficacy expectations influence outcome expectations, and that these two constructs, in turn, influence interests. According to Bandura (1986), self-efficacy expectations are defined as '(…) people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances' (Bandura, 1986, p. 391), whereas outcome expectations are defined as '(...) beliefs about the consequences or outcomes of performing particular behaviors' (Lent, 2020, p. 133). Positive outcome expectations and high self-efficacy expectations promote interest in an activity, and interests alsong with outcome expectations and self-efficacy expectations, in turn influences career aspirations (Lent & Brown, 2019; Lent, 2020).

According to Prenzel et al. (1986), interest can be understood as a person-object relationship. Interest is characterized in particular by positive emotions and appreciation for the object of interest, with a desire to expand one's knowledge also playing a central role (Krapp, 2018). Overall, a distinction can be made between situational interest, that is, an externally triggered interest, and individual interest as a permanent trait (Schiefele, 2008). In principle, individual interests arise from situational interests, which are stimulated by specific factors and can develop into individual interests through a multi-stage process (Krapp, 1998). Ultimately, a stable individual interest is anchored in the personality and linked to a sense of identification (Krapp, 2018).

In the context of SCCT, it is important to note that individuals are also influenced by their environment and that the role of interests in the actual decision-making process can be limited by external influences (Lent, 2020).

Luo et al. (2021) found that STEM stereotypes can negatively impact self-efficacy in STEM, career-related STEM outcome expectations and, mediated by these constructs, primary school students' interest in STEM careers (Luo et al., 2021). Accordingly, 'Educators should pay attention to students' stereotypes regarding STEM careers and attempt to transform stereotypical conceptions of STEM careers into more realistic and diversified conceptions (…)' (Luo et al., 2021, p. 11). Thus, measures to reduce STEM stereotypes will be integrated into the intervention as an approach to increasing STEM career aspirations. The following section outlines how stereotypes arise, which stereotypes exist in the STEM field, and how they could be diversified.

Following the American Psychological Association, we define stereotypes as cognitive generalizations about group members or a social category (VandenBos, 2015). They '(…) simplify and expedite perceptions and judgments, but (...) are often exaggerated, negative rather than positive, and resistant to revision even when perceivers encounter individuals with qualities that are not congruent with the stereotype (…)' (VandenBos, 2015, p. 1031). Nevertheless, stereotypes can be changed (Elsen, 2023). The following is a brief, albeit far from exhaustive, overview of the cognitive and motivational processes that can give rise to stereotypes.

Cundiff (2020) summarizes that, from a cognitive perspective, stereotypes arise from the natural human tendency to process and categorize information. This shows that stereotypes are linked to social categorization and

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that social categorization is a necessary condition for them (Klauer, 2020). Such categorization contributes to the simplification and structuring of social situations (Klauer, 2020). During classification, differences between classes in a continuous characteristic associated with the classification tend to be exaggerated between those classes and minimized within each class (Tajfel, 1969). This is also evident in part empirically (McGarty & Turner, 1992; Tajfel & Wilkes, 1963) and, when applied to human characteristics, could partly explain the emergence of stereotypes (Tajfel, 1969). However, the perception of homogeneity within the in-group in the course of classification, as postulated by Tajfel and Wilkes (1963), could not be empirically proven or replicated (Spears & Stroebe, 2015). Another cognitive explanation for the emergence of stereotypes can be found in the concept of illusory correlation, which assumes that the simultaneous occurrence of two unlikely events, for example in relation to behavior and group membership, can lead to a perceived relationship between them (Hamilton & Gifford, 1976). Therefore, the illusory correlation approach explains stereotypes as based on biased judgments (Hamilton & Gifford, 1976) rather than, as in Tajfel and Wilkes (1963), on reality. Nevertheless, Spears and Stroebe (2015) summarize that various explanatory approaches view stereotyping processes as not necessarily affected by bias, although the ultimate question of whether they are based on reality remains controversial. Nevertheless, Hamilton and Gifford (1976) emphasize the role of learning processes in stereotype development, and Tajfel (1969) also stresses that the content of categories people are assigned to is generated within a culture over the long term and transferred to individuals as a form of social learning.

In principle, various perspectives on stereotype formation exist (McGarty & Turner, 2002). In addition to these approaches, stereotypes can also be justified from a motivational perspective (Cundiff, 2020). Here, Cundiff (2020) summarizes that stereotypes can improve the ego-related or group-related self-image or justify existing role and status differences. In relation to a group-related self-image, the Social Identity Theory of Tajfel and Turner (1979) argues that individuals try to establish a positive social identity that stems from a sense of belonging to social groups. One approach that shares many characteristics with social identity theory is self-categorization theory, proposed by Turner et al. (1987), although some authors, while acknowledging these parallels and without ignoring the differences between the two approaches, refer to them collectively as the social identity approach (Hornsey, 2008). Junker et al. (2024) summarize that the Social Identity Approach essentially posits that people's self-concept consists of a personal and a social identity, with individuals moving along a continuum between these identities depending on the situation. Within Social Identity Theory, Tajfel and Turner (1979) emphasize that especially positive comparisons with other groups contribute to a positive social identity, so that individuals are under a certain pressure to evaluate their own in-group positively through comparisons (Tajfel & Turner, 1979). With an unsatisfactory social identity, individuals can tend to leave their social group or accentuate it more positively (Tajfel & Turner, 1979). The Social Identity Approach thus posits that individuals can develop a certain degree of in-group bias and wish to distinguish themselves positively from out-groups (Verkuyten, 2021). Jost and Banaji (1994) offer a complementary approach to why groups can also tend toward negative self-stereotyping. They attribute a system-justifying function, albeit often unconscious, to some stereotypes based on psychological mechanisms (Jost & Banaji, 1994).

The STEM field is particularly affected by occupational stereotypes (Van Tuijl & Van Der Molen, 2016). Given the global underrepresentation of women in some STEM fields (Cheryan et al., 2025), research and discussion have focused on gender and gender-related stereotypes (Van Tuijl & Van Der Molen, 2016). McLure et al. (2025) summarize that STEM is perceived as a masculine field. Cheryan et al. (2025) emphasize that masculine culture prevails in STEM, characterized by masculine defaults and differential treatment of women. Masculine defaults are generally understood to be a bias in which behaviors or characteristics associated with men are viewed as positive or normal, resulting in disadvantaging women (Cheryan & Markus, 2020). In STEM, these defaults include stereotypes that, for example, portray STEM occupations as solitary or brilliant (Cheryan et al., 2025).

Furthermore, stereotypes also contribute to the different treatment of women or affect their behavior due to stereotype threat (Cheryan et al., 2025). Fink et al. (2025) found that in-service and pre-service school teachers in Germany expected boys to be more competent than girls in mathematics, natural science, engineering, and computer science, although this difference in expectations was not significant among in-service teachers in natural science. The difference in perceived competence was particularly pronounced in the sub-areas of engineering and computer science (Fink et al., 2025). In a recent literature review, Cardelli et al. (2026) conclude that, regarding career choice, the studies examined "highlight that gender stereotypes are associated with more gender-stereotypical career interests and choices in both women and men, and with lower career aspirations in women" (p. 10).

Finally, to change gender-related stereotypes, Cheryan et al. (2015) propose interventions in the environment, media, and representatives. In this context, an inclusive culture should be created, for example, by consciously selecting representatives, creating welcoming physical spaces, and changing media narratives about who belongs in the respective field (Cheryan et al., 2015).

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Nevertheless, a sole focus on gender in relation to STEM can obscure the intertwining of gender with other identities such as nationality, and it can therefore be expected that different marginalized groups will also be confronted with different experiences and may require different interventions (Cheryan et al., 2025). This approach aligns with findings on gender stereotypes, as manipulating visual or textual factors can causally influence career interests and intentions (Cardelli et al., 2026). Steinke and Duncan (2023), for example, showed that an intervention involving hands-on STEM activities and an interactive presentation on STEM stereotypes can impart career-related knowledge and influence perceptions of people working in STEM occupations.

Cheryan et al. (2015) point out that their intervention approach in relation to computer science and technology is useful not only for promoting girls but also boys. This is because the authors argue for diversifying stereotypes rather than changing them entirely, helping ensure that men and women interested in computer science and technology careers because of stereotypical ideas are not deterred (Cheryan et al., 2015). Overall, a broader image of these occupations also corresponds more closely to reality and avoids an unrealistic narrowing (Cheryan et al., 2015). In addition, the authors point out that there are certainly some men who prefer non-stereotypical environments (Cheryan et al., 2015). Diversifying STEM career perceptions could thus have a particularly positive impact on the STEM career aspirations of students of all genders, provided that the arguments presented are applied beyond a binary understanding of gender. We assume that such diversification should not be exclusively gender-related, as Cheryan et al. (2025) mention that focusing solely on gender masks its intertwining with other identities.

Based on these assumptions, we designed an out-of-school intervention, which has already been evaluated in a different format by Romanik and Wegner (2025b) and Romanik et al. (in press), and which attempts to diversify stereotypes through, among other things, videos with AI-generated content. The goal in this context is to develop an DBR-based intervention that increases students' interest in STEM careers and can be used to compare learning environments (Romanik & Wegner, 2025a). Both previous evaluations of the first intervention design (Romanik & Wegner, 2025b; Romanik et al., in press) showed positive signs of the intervention approach, but also highlighted areas in need of revision, with the quantitative evaluation (Romanik & Wegner, 2025b) showing no statistically significant effectiveness of the video use. The present study examines, as recommended by Romanik and Wegner (2025b), the effects of an improved intervention with a more diverse sample and, in addition to these recommendations, incorporates a gender perspective.

The study will examine the effects of the intervention approach on constructs relevant to the development of STEM career aspirations in the sense of SCCT and consider gender-dependent developments. This raises the following research questions:

What influence does the designed intervention have on students´...

Q1: … career-related STEM self-efficacy?

Q2: … career-related STEM outcome expectations?

Q3: … individual STEM interests?

Q4: … STEM career aspirations?

Does the pre-post comparison reveal gender-dependent developments in students´ ...

Q5: … career-related STEM self-efficacy?

Q6: … career-related STEM outcome expectations?

Q7: … individual STEM interest?

Q8: … STEM career aspirations?

The development of individual interests begins with an externally triggered, situational interest (Krapp, 1998). In the classroom, both situational and individual interests must be considered relevant objectives (Krapp, 1998). The goal of diversifying existing STEM stereotypes to inspire students, with an expected impact especially on students who identify with the female gender role, suggests a gender-based analysis of the expression of situational interests:

Q9: What gender-based differences exist in the expression of situational interest towards the content of the STEM intervention conducted?

Based on the theoretical assumptions and the revised intervention approach described, we assume the intervention will positively influence self-efficacy and outcome expectations in particular, and thus also interests and career aspirations, among other things, by reducing stereotypes. Nevertheless, we expect a short-term intervention not to increase individual interest as a long-term disposition but to trigger situational interest.

The designed intervention …

H1. … significantly increases students' career-related STEM self-efficacy.

H2. … significantly increases students' career-related STEM outcome expectations.

H3. … does not significantly change students' individual STEM interest.

H4. … significantly increases students' STEM career aspirations.

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One reason for the underrepresentation of women in STEM fields is the stereotypically perceived and actually existing masculine culture in these occupations (Cheryan et al., 2025). We assume that diversifying certain STEM stereotypes as part of this masculine culture during the intervention will have a positive impact on all genders, even though we expect students who identify with the female gender role in particular to benefit from diversification, as masculine defaults, according to Cheryan et al. (2025), can contribute to discouraging women from STEM. The following hypotheses are formulated:

The designed intervention …

H5. … increases the career-related STEM self-efficacy …

H6. … increases the career-related STEM expectations …

H7. … does not result in gender-based differences in the development of individual STEM interest.

H8. … increases the STEM career aspirations …

… among students who identify with the female gender role significantly more than among students of different genders.

Since the intervention is expected to have a particularly positive impact on students who identify with the female gender role, their situational interest in the intervention content should be higher.

H9. The situational interest in the intervention content in the post-test is significantly higher among students who identify with the female gender role than among students of different genders.

METHODS

Implemented intervention

The intervention approach described by Romanik and Wegner (2025b) and Romanik et al. (in press) was adopted in the present study and revised in accordance with the authors' recommendations.

For the intervention, regular school classes visited the out-of-school student laboratory Kolumbus-Kids for a full-day workshop lasting 6.5 hours, during which $N = 75$ students participated in a questionnaire survey conducted at least once at one of two test time points within the workshop. The students worked on programming a smart terrarium for the university zoo. They were first introduced to programming theory and algorithmic logic by creating flowcharts before being introduced to the Calliope mini microcontroller. The Calliope mini is a microcontroller developed for educational purposes and is particularly suitable for an accessible introduction to programming in the MakeCode editor because of its block- and text-based programming options (Romanik & Wegner, 2025c). Students first learned about the Calliope mini and practiced programming it. They then received a video assignment from a zookeeper, who tasked them with designing smart terrariums. After clarifying the assignment, the students were introduced to additional external sensors and actuators. Building on this knowledge, they began working in groups to create semi-automated plant terrariums that automatically measured soil moisture and light, for example. The day ended with the group work results being saved. In addition to the videos, explained below, the collaborative group work and patient, empathetic support from two supervisors are intended to reduce stereotypes and provide positive, performance-related experiences as a source of STEM-related self-efficacy.

Throughout the intervention, students watched videos with AI-generated content designed to portray STEM occupations in a non-stereotypical and diverse manner. Therefore, to account for the Kolumbus-Kids out-of-school learning environment at Bielefeld University, the occupations shown were limited to those requiring a university degree. The videos and activities depicted were structured using the RIASEC+N dimensions, following Dierks et al. (2014). In terms of content, AI-generated images of STEM occupations were shown, depicting people performing various activities, accompanied by an audio explanation of the different aspects of the activities in line with RIASEC+N. Students were presented with three videos ranging from 1:30 to 2:41 minutes at regular intervals. During group work, the generated images were also shown as a slideshow without audio in the classroom.

Each student further received an observation sheet on which they were asked to note which aspects of the videos they were already familiar with and which were new to them. We added a field for open questions to the observation sheet. At the end of the intervention, the students' notes were discussed in a plenary session, and open questions were addressed. Overall, this approach addresses the limitations of previous implementations highlighted by Romanik and Wegner (2025b) and Romanik et al. (in press) and revises the original intervention approach so the unit's workload is spread over a longer intervention period and thus reduced, and the videos are integrated more comprehensively and explicitly. Both Romanik and Wegner (2025b) and Romanik et al. (in press) reported that students had difficulty understanding the term STEM, so it has now been defined more precisely for the students. Referring to Cheryan et al. (2015), the use of video was intended to present a more diverse picture of STEM occupations, to tell different stories about the people who belong to STEM occupations, and to create a more inclusive physical space by projecting the AI-generated images in the form of a slideshow in the room.

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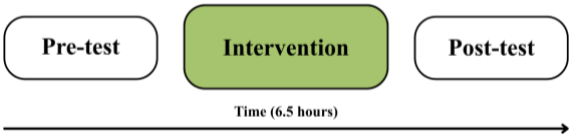
Surveys were conducted in the form of quantitative pre- and post-tests immediately before and at the end of the intervention (Figure 1). Participation in the surveys was voluntary for all students and required consent from their legal guardians, with no disadvantages associated with non-participation.

Figure 1

Schematic overview of the data collection process during the intervention timeframe



Sample

n = 74 (n_{male} = 39 (52.70%); n_{female} = 35 (47.30%)) children participated in the pre- and post-tests, with one child from the original N = 75 (n_{male} = 40 (53.33%); n_{female} = 35 (46.67%)) dropping out of the post-test. Excluding two children who stated their own age as 210 and 2 from N = 75, the average age was M = 11.08 (SD = 0.91), with n = 73 children providing this information. From N = 75 children, n = 25 attended a comprehensive school and n = 50 attended a grammar school.

Data collection

A quantitative questionnaire captured the constructs specified in the research questions and hypotheses. The following table (Table 1) provides an overview of the constructs included in the questionnaire and assigned Cronbach's alpha values as a measure of internal consistency. In the original publication, the constructs individual STEM interest and situational interest, which have been adapted for this study, were not analyzed using factor analysis (Wegner, 2009). To perform this analysis at least once and further validate the quality of these two constructs, this study conducted a confirmatory factor analysis. STEM interest was measured in the pre- and the post-test, whereby the factor analysis was conducted using post-test data because the term STEM should have been most clearly defined in the post-test due to the intervention.

Table 1

Structure and Reliability of the Questionnaire Used

Construct	Example item	Item number	Cronbach's Alpha
Career-related STEM self-efficacy expectations (OSE) [Adapted according to Mohr, 2022]	I know that I can meet the requirements for a STEM occupation.	4	.816-.822
Career-related STEM outcome expectations (OOE) [Reduced, translated and adapted according to Luo et al., 2021]	In a STEM occupation, I can help others.	4	.768-.792
Individual STEM interest (SI) [Adapted according to Wegner, 2009]	Dealing with STEM improves my mood.	6	.898-.908
STEM career aspirations (SCA) [Adapted according to Mohr, 2022]	I would like to start a training program or study in the STEM field.	4	.927-.927
Situational interest in the content of the intervention carried out (SSI) [Adapted according to Wegner, 2009]	The work in the course made me very curious	4	.870

All constructs were linguistically adapted to the occupational STEM context so that, for example, career-related STEM outcome expectations were captured. Only individual interest was linguistically oriented toward STEM topics in general and, in the case of situational interest, towards the content of the conducted intervention. One item of the individual STEM interest construct was reverse-coded. This was intended allow the authors to identify response bias and, if necessary, exclude individual participants from the statistical analysis of the results due to conspicuous response behavior. All items were answered on a Likert-style scale from 1 to 6.

Because the data analysis focused on gender, participating students provided their gender, referred to as sex, to better understand the young sample. The response options available were male, female, and diverse, with diverse

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encompassing all inter* and trans* identities. We explained these options in more detail to students upon request. All gender references in the sample in the following chapters are based on this statement. All analyzed data were fully available to the authors.

RESULTS

To examine both intervention effects over time and gender-dependent developments, mixed ANOVAs were performed with the within-subject factor time and the between-subject factor gender for the constructs OSE, OOE, SI, and SCA. To analyze gender-based differences in SSI scores in the post-test, an unpaired t-test was calculated. Before performing the calculations, the data set of $N = 75$ students was reduced by excluding from the analysis those cases that answered all items of the SI construct identically, including one inverted item, resulting in a subsample of $n = 72$.

To assess the quality of the SI and SSI constructs before calculating the mixed ANOVAs, a confirmatory factor analysis was performed with this subsample of $n = 72$. For the SSI construct, the results were a χ^2 value of 0.073, a RMSEA of 0.151, a CFI of 0.983, a TLI of 0.950, and a SRMR of 0.033. For SI, the results were a χ^2 of 0.527, a RMSEA of 0.000, a CFI of 1.000, a TLI of 1.006, and an SRMR of 0.030. Thus, all values, except for the RMSEA for SI, fall within the acceptable range (Hooper et al., 2008). Kenny et al. (2015) demonstrated that the RMSEA becomes prone to error when N and df are small and, in such cases, should not be used alone to assess model fit. In the present study, a relatively small sample of $n = 72$ was examined, whereby df for SSI in the factor model was 2. This could explain the high RMSEA for SSI despite acceptable values for the other fit indices, so that overall, the assumed one-factor structure is accepted for both constructs.

Some sources that recommend excluding outliers when calculating an ANOVA, as they influence variances and the assumptions of a normal data distribution and homogeneity of variances in a special way (Backhaus et al., 2025). This was done after excluding cases on the basis of the inverted items by using boxplots and excluding those individuals that were placed below the 25th percentile – 1.5 x interquartile range or above the 75th percentile + 1.5 x interquartile range. The same was done for each construct at both measurement points and for both genders specified. A total of $n = 4$ cases were deliberately excluded for SI, $n = 3$ for OSE, $n = 4$ for OOE, and $n = 1$ for SCA.

Due to missing values and exclusion of outliers in the sample of $n = 72$, the subsamples used for the individual calculations in the mixed ANOVAs that were conducted were $n_{male} = 34$ and $n_{female} = 33$ for SI, $n_{male} = 33$ and $n_{female} = 34$ for OSE, $n_{male} = 33$ and $n_{female} = 33$ for OOE, and $n_{male} = 36$ and $n_{female} = 33$ for SCA.

For a t-test, the exclusion of outliers is not defined as a necessary assumption (Bortz & Schuster, 2010). In addition to the exclusion using an inverted item, as already explained, the sample for SSI is based solely on missing values and consists of $n_{male} = 36$ and $n_{female} = 35$.

Regarding the calculation of mixed ANOVAs, homogeneity of error variances was met for all groups, with the exception of one case, based on a Levene's test ($p > .05$). In the pre-test, SCA showed a significant Levene's test ($p = .019$). Field (2009) summarizes that, for samples of equal size, ANOVA is quite robust to non-homogeneous variances. Since the sample sizes for SCA are $n_{male} = 36$ and $n_{female} = 33$, it is assumed that the mixed ANOVA can be performed accordingly. Apart from that, Hsu (1996) also notes that 'An unfortunate common practice is to perform multiple comparisons *only* when the null hypothesis of homogeneity (...) (typically based on the F-test) is rejected (...)' (p. 177). Accordingly, the post-hoc comparisons could be interpreted despite a significant Levene's test. A normal distribution of data was assumed for all combinations of within- and between-subject factors for the constructs examined, since n was > 30 for each combination and, based on the central limit theorem, a normal distribution of data can be assumed for sample sizes of this size (Bortz et al., 2010).

An interaction effect of the factors time and gender is not evident for the OSE construct $F(1.00, 65.00) = 0.20$, $p = .656$, nor in the construct OOE $F(1.00, 64.00) = 0.09$, $p = .769$, nor in the construct SCA $F(1.00, 67.00) = 2.87$, $p = .095$. Only regarding SI, a significant interaction effect was found $F(1.00, 65.00) = 5.97$, $p = .017$, partial $\eta^2 = .08$.

Bonferroni-corrected post-hoc tests showed a significant reduction in SI among female students from pre-test ($M = 3.43$, $SE = 0.17$) to post-test ($M = 2.99$, $SE = 0.18$, $p = .003$, $d = 0.44$), while all other comparisons were not significant ($p > .05$). **Figure 2** shows gender-dependent means in the pre- and post-test.

Only in relation to SI was there a significant main effect of the within-subject factor time $F(1.00, 65.00) = 7.45$, $p = .008$, partial $\eta^2 = .103$. In this context, **Figure 3** and a post-hoc comparison show a decline in the SI from pre-test ($M = 3.30$, $SE = 0.12$) to post-test ($M = 3.07$, $SE = 0.13$, $p = .008$, $d = 0.23$). No main effect of time was found for OOE $F(1.00, 64.00) = 0.78$, $p = .381$, OSE $F(1.00, 65.00) = 0.001$, $p = .971$, and SCA $F(1.00, 67.00) = 0.51$, $p = .480$.

A significant main effect of the between-subject factor gender was found for OSE $F(1.00, 65.00) = 4.33$, $p = .041$, partial $\eta^2 = .06$. Female students ($M = 3.01$, $SE = 0.16$) generally had a lower OSE than the male students

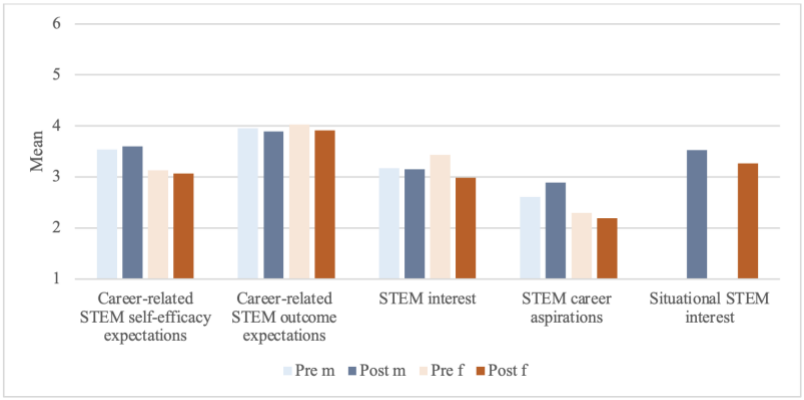
(M = 3.57, SE = 0.16, p = .041, d = 0.44). No significant main effect was found for OOE F(1.00, 64.00) = 0.05, p = .817, SI F(1.00, 65.00) = 0.05, p = .822, and SCA F(1.00, 67.00) = 3.40, p = .070. **Figure 3** shows gender-independent means of the constructs in the pre- and post-test.

Based on the preceding discussion regarding the error variances for the SCA construct, the post-hoc tests of the mixed ANOVA were examined, regardless of any interaction or main effects that occurred. No significant results (p > .05) were found.

With regard to the calculation of an unpaired t-test for SSI to analyze gender-based differences, a normal distribution of the data is again assumed based on the sample sizes of n_{male} = 36 and n_{female} = 35. In addition, a non-significant (p > .05) Levene's test indicated homogeneity of variances. A one-sided Student's t-test showed that female students (M = 3.27, SE = 1.02) had no significantly higher SSI scores than male students (M = 3.53, SE = 0.24) in the post-test t(69) = 0.86, p = .803.

Figure 2

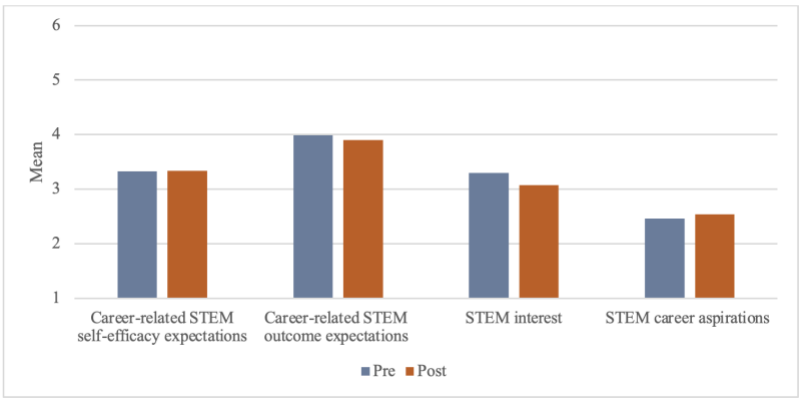
Gender-Dependent Construct Means in Pre- and Post-Test



Note. M stands for male and f for female. Pre is an abbreviation for the pre-test and Post an abbreviation for the post-test.

Figure 3

Gender-Independent Construct Means in Pre- and Post-Test



Note. Pre stands for mean values for the pre-test and post for mean values for the post-test.

DISCUSSION

H1 to H9 must be rejected. The designed intervention did not increase any of the constructs examined. There was even an unexpected, significant reduction in SI from pre- to post-test. Female students did not develop more positively than male students. In fact, female student's SI decreased significantly, while no change was observed among male students. SSI was not significantly higher among female students in the post-test, and descriptive data even showed a lower score (**Figure 3**). Overall, the results indicate an ineffective intervention that negatively affected female students and did not increase STEM career aspirations.

Additionally, OSE showed a significant main effect of gender, with female students scoring lower than male students regardless of testing time. This is consistent with reports of lower self-efficacy in computer science and mathematics among girls and women in other geographical contexts, such as the USA and Canada, where evidence of this gender-specific difference is mixed in some STEM fields (Cheryan et al., 2025). Mohr (2022) has already shown that OSE is less pronounced among 8th-grade female students than among 8th grade male students. This gender-related difference in OSE thus confirms findings from other studies and contexts and highlights the need

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for special support for girls in STEM subjects. The low OSE could also result from the stereotype threat effect. In their review, Cardelli et al. (2026) note that simply being aware of the risk of conforming to stereotypes can already influence career aspirations. Cheryan et al. (2025) emphasize that awareness of negative gender stereotypes can lead to less interest and fewer women participating in STEM fields. Some authors (von Hippel et al., 2026; Xu, 2025), emphasize that stereotype threat could be negatively connected to self-efficacy as well. It is therefore possible that the female students, particularly if they had formed same-sex groups, may have been affected by the stereotype threat effect, thereby negatively impacting their OSE. This may also have been intensified by what felt like a competitive situation, where different groups were working on comparable projects. The gender-based differences in OSE thus appear to support the outlined influence of the stereotype threat effect on women's behavior in STEM contexts (Cheryan et al., 2025).

Some results do not correspond to expectations based on theoretical connections. One would expect that, in line with SCCT (Lent, 2020), a significant reduction in the SI of female students would also be accompanied by a significant reduction in their OSE and OOE. This lack of statistical significance among female students may be due to sample size. Nevertheless, it would be useful to further investigate the assumed causal relationships of the SCCT. Therefore, a measurement instrument for assessing STEM stereotypes should be included in a further revision and evaluation cycle of the intervention. The lack of such an instrument is also a weakness of the study presented.

Various explanations for SI decline among female students appear plausible. Cheryan et al. (2025) emphasized the importance of reducing, for example, the perception of masculine defaults in STEM occupations to support women and girls in entering STEM occupations. The fact that only female students experienced a decline in their SI could be because the intervention did not reduce this perception of masculine defaults but instead confirmed or increased it. This may be particularly true given the intervention's thematic focus, as Master et al. (2025) showed that, in computer science in particular, students are strongly affected by the stereotype that boys are more interested in and better at this field. This may not have produced a significant reduction in OOE, OSE, or SCA because of the sample size. The fact that female students did not have a significantly higher, and in fact descriptively lower, SSI supports this impression. Because female students showed no reduction in SCA despite a reduction in SI, this may also reflect that proximal contextual influences moderate the influence of SI on SCA, as these influences also directly shape goal formation (Lent, 2020). Contextual influences that, despite a decline in SI, might not lead to a decline in SCA could, for example, include that even students may reflect the open positions in STEM occupations when making career aspirations. Nevertheless, the findings should be interpreted with caution and verified using a larger sample, as they partly do not align with theoretical assumptions. As such, dispositional interest is defined as a time-stable disposition (Schiefele, 2008). The observed decline in SI among female students following a short-term intervention therefore appears unusual and could, for example, be due to the relatively small subsample size. At the same time, the students may have linked the more general items regarding the SI construct in the post-test more specifically to the intervention content, so the post-test items may have been interpreted differently.

A reduction in STEM stereotypes was to be achieved not only through the didactic design of the tasks, but also through the use of videos. The didactic task design may not yet sufficiently distance itself from stereotypically masculine characteristics such as independence or autonomy (Cheryan & Markus, 2020) and should place greater emphasis on cooperative work and exchange. Furthermore, interpersonal relatedness is considered a basic psychological need (Deci & Ryan, 1985). The development of interests depends largely on the satisfaction of such needs (Krapp, 1998). Therefore, increased cooperation could also support the development of interests. Further, the designed videos could not have been perceived attentively by the students, as was also the case in the first piloting of the intervention concept (Romanik & Wegner, 2025b; Romanik et al., in press), and their content was therefore not perceived in a lasting way. The approach taken to producing observation notes may not have been sufficient to draw students' attention more intensively to the video content. Future intervention designs should integrate the video content more comprehensively to draw more attention to it.

It is further possible that many students were unable to identify with the adults in the videos. This presents a certain dilemma. On the one hand, Bandura emphasizes that '(...) visualizing other similar people perform successfully can raise self-perceptions of efficacy in observers (...)' (Bandura, 1986, p. 399). Therefore, it is questionable whether students perceive adults as identical to themselves and thus their success in a STEM occupation as a proxy source for increasing their own OSE. On the other hand, a realistic and authentic portrayal of the people working in STEM occupations relies on the visualization of adults. This situation could be improved by incorporating a younger AI avatar into the videos. Such an avatar, in the form of a young girl, for example, could introduce aspects of STEM occupations to the students in a child-friendly way and create opportunities for identification. This could capture students' attention, provide a female role model as a STEM expert, and open the possibility of using the corresponding avatar in, for example, written materials for the course day. Since experiences of success are still considered the primary source of self-efficacy (Bandura, 1986), it is also possible that the tasks set in the intervention were still too complex for the students to complete successfully. While this, along with the

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lack of identification options, does not necessarily explain gender-related differences, it could, like the other points for revision, have contributed to the intervention not leading to a significantly increased perception of OSE or OOE among students. If we also assume that female students in the sample are less likely to come into contact with programming activities due to the obstacles mentioned in the theory section, the complexity and scope of the tasks could also explain why their OSE decreased descriptively, while that of male students increased descriptively (**Figure 2**). Differences in prior knowledge may have contributed to male students perceiving less difficulty in completing the tasks than female students. Further revisions should reduce task complexity, and it may be sensible to support higher-performing students through individual differentiation.

Further limitations include that the variance was not homogeneous in the pre-test for the SCA construct. Given that the samples were nearly identical, it was assumed that the mixed ANOVA would be robust. Nevertheless, the results regarding SCA, in particular, must be interpreted with caution. Furthermore, because the analysis was split by gender, the statistical tests were based on relatively small subsamples, leaving it unclear how well the results would replicate in a larger sample. In general, because no follow-up test was conducted, it remains unclear how sustained the observed developments in the examined constructs were. This must be taken into account particularly with regard to the SI construct, as a measurement instrument by Wegner (2009) was used here, which assesses long-term dispositions.

Overall, it remains unclear, particularly with regard to SSI as a construct related to the intervention, to what extent students may have responded in a socially desirable manner. It is further possible that the students did not have a consistent and realistic understanding of the term STEM, or that their understanding only became realistic as a result of the intervention.

CONCLUSION

As part of a long-term research project, this study aimed to design an intervention to increase students' STEM career aspirations. Specifically, the study aimed to diversify STEM stereotypes, in part by using generative AI in informational videos. It was assumed that the intervention would have a positive influence on key constructs of the SCCT and lead to more positive outcomes among female students, as women are particularly disadvantaged by the stereotypically masculine culture within STEM. The intervention was implemented in an out-of-school science laboratory, and quantitative questionnaire data from pre- and post-tests involving $n = 72$ children were analyzed using mixed ANOVAs.

None of the hypotheses were confirmed, suggesting the intervention did not increase STEM career aspirations. Rather, it seems to have a negative impact, particularly on female students. Those students also showed a lower overall OSE. This reduction in SI, together with a low OSE, suggests that women and girls in Germany, too, are negatively affected by STEM stereotypes. Given the limited effectiveness of the current intervention approach, initial recommendations for didactic practice can be derived. Teachers should create an inclusive learning environment that does not reinforce an exclusively masculine STEM culture and ensure, in particular, that student's basic psychological needs are met. Informative elements should be incorporated into activities in a way that gives them meaning, so students focus their attention on them. Further research is needed on the benefits of AI-generated visual elements, whereby it seems sensible to involve younger individuals in the material with whom students can identify.

This study aimed to evaluate a revised version of an intervention design described by Romanik and Wegner (2025b) and Romanik et al. (in press) based on the DBR approach in terms of its suitability for increasing STEM career aspirations and related constructs among students. The intervention should be used further for a comparison of learning places. DBR approach involves developing a solution to a practice-relevant educational problem through the iterative refinement of a developed design, while also further developing a relevant theory (Schmiedebach & Wegner, 2021). Accordingly, the presented intervention must be adapted and evaluated in a new cycle, in which the points discussed are addressed. A further revision should, for example, reduce task complexity, focus more on cooperative working methods, and integrate the videos more strongly into the intervention by using a female avatar. A subsequent evaluation should include a measurement instrument to assess STEM stereotypes. In line with its iterative nature, revising an intervention design is not a problem in the DBR framework, but rather aligns with the approach outlined by Schmiedebach and Wegner (2021) of using the revision needs identified through analytical results to guide a new evaluation cycle. Further revisions could lead to an effective intervention that is suitable for the outlined learning place comparisons.

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Ethical statement

A statement of ethical approval from the Ethics Committee of Bielefeld University, under reference EUB-2025-370, has been obtained.

Competing interests

The authors declare that there are no competing interests regarding the publication of this paper.

Author contributions

The authors listed were involved in project administration, resource management and the validation of the research process. Author one was responsible for methodological planning, data collection, data analysis and the preparation of the manuscript. Author two contributed to the review and editing of the manuscript and led the funding acquisition that made this study possible.

Data availability

The analyzed data were collected as original data and are stored locally on storage media at Bielefeld University. For data protection reasons, the original data cannot be made publicly available.

AI disclosure

The authors did not use generative AI tools in the preparation of this manuscript, its text, figures, or underlying data. AI-assisted translation tools were used during the translation and linguistic revision of the manuscript.

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