frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 01 December 2022
DOI 10.3389/feduc.2022.957716

OPEN ACCESS

EDITED BY
Karen Blackmore,
University of Worcester,
United Kingdom

REVIEWED BY
Jessica Gladstone,
New York University, United States
Luiz M. G. Gonçalves,
Federal University of Rio Grande do Norte,
Brazil

*CORRESPONDENCE
Antonia Ladewig
ladewig@leibniz-ipn.de

SPECIALTY SECTION
This article was submitted to
STEM Education,
a section of the journal
Frontiers in Education

RECEIVED 31 May 2022
ACCEPTED 07 November 2022
PUBLISHED 01 December 2022

CITATION
Ladewig A, Köller O and Neumann K (2022) Stereotypes in the German Physics Olympiad - Hurdle or no Harm at all? *Front. Educ.* 7:957716.
doi: 10.3389/feduc.2022.957716

Stereotypes in the German Physics Olympiad - Hurdle or no Harm at all?

Antonia Ladewig[1]*, Olaf Köller[2] and Knut Neumann[1]

[1]Department of Physics Education, Leibniz Institute for Science and Mathematics Education, Kiel, Germany, [2]Department of Educational Research and Educational Psychology, Leibniz Institute for Science and Mathematics Education, Kiel, Germany

The German Physics Olympiad is a science competition in which students can compete to measure their Physics knowledge and skills with other students. Female participants are underrepresented and typically drop out of the competition earlier than their male counterparts. As the cause for this underrepresentation, social identity threat theory identifies a threat to women's gender identity in the predominantly male environment. Stereotype threat theory adds negative stereotypes about women's abilities in physics as a heightening factor. In this study, growth mindset and values affirmation interventions, as well as a combination of both methods, were integrated into a weekend seminar of Physics content to protect female participants from the harmful influences of stereotype and social identity threat. As female and male students' sense of belonging and gender identification remained at equal levels, respectively, after the interventions, the results did not show any effects of stereotype threat or social identity threat for the female students. The results suggest that women who are highly interested and talented in physics and have taken first steps to pursue physics and to engage with the physics community beyond mandatory school education are not as susceptible to stereotypes and harmful cues in the environment as might previously have been assumed. Implications for future research and science competitions are discussed.

KEYWORDS

stereotypes, social identity threat, stereotype threat, science competitions, physics

Introduction

Why are females still a minority in physics? One reason for the underrepresentation of women that is discussed in the literature is stereotype threat, that is, the phenomenon that minorities start to unconsciously live up to negatively stereotyped behavior in fields consisting of a predominant majority (e.g., Steele and Aronson, 1995; Steele et al., 2002; Hall et al., 2015; Bedyńska et al., 2018). Women are affected by this as they are underrepresented in many science environments and faced with stereotypes of lacking science talent.

Previous research introduced various interventions to fight stereotype threat (e.g., Cheryan et al., 2011; Lin-Siegler et al., 2016). As the mere presence of negative stereotypes might lead to stereotype threat effects (e.g., Huguet and Régner, 2009; Marchand and Taasobshirazi, 2013) and its various negative consequences (e.g., Schmader and Johns, 2003; Hall et al., 2015, 2018), interventions aim to shield minority groups from stereotype threat instead of eliminating stereotypes from the environment. Especially two short intervention methods showed noticeable success: First, interventions that aim to reduce the impact of stereotypes by teaching students about the malleability of the brain, the use of effort, and struggle to gain success (growth mindset; e.g., Blackwell et al., 2007; Yeager et al., 2016), and, second, interventions that affirm participants in their values (values affirmation; e.g., Cohen et al., 2006, 2009).

However, these interventions have not yet been tested with the important sample of students who chose to engage in extracurricular science activities. These students show interest and intention to engage in the domain by pursuing science outside the mandatory school curriculum. Nonetheless, female students who participate in such extracurricular science activities experience stereotype threat (see Ladewig at al., 2020).

In this study, participants in the German Physics Olympiad, a physics competition, were invited to physics seminars. In these seminars, students participated in either an intervention of growth mindset, an intervention of values affirmation, or a combination of both. We investigated how the different short interventions impacted sense of belonging, social identity threat, stereotype endorsement, perceptions of environmental stereotyping, and gender identification.

Theoretical background

The German Physics Olympiad presents a science environment, which students encounter outside of their mandatory school education. Students decide freely whether they want to participate in the competition. However, female students decide to do so not as often as the male students. Which are the driving influences leading to this gender gap?

Underrepresentation of women in science

Females in science face stereotypes about women having supposedly lower talent or not fitting within the male in-group. In line with the stereotypical association of sciences with the male gender (see Makarova et al., 2019), only about every fifth academic in science, technology, engineering, or mathematics fields in Germany is female (Anger et al., 2019). This underrepresentation of women begins with decreasing science interest in school for girls but not for boys (Sadler et al., 2012) and ends with low numbers of women in science careers (e.g., Kahn and Ginther, 2015; Miller and Wai, 2015; Su and Rounds, 2015). Although the gender gap is less pronounced in some domains, it is very distinct in physics (e.g., Düchs and Mecke, 2019). But why is science such a hindering environment for females?

Science provides cues that drive many women from the field. A person remains in an environment if their perception of their self fit to the person stereotypically expected in the environment (e.g., Setterlund and Niedenthal, 1993; Hannover and Kessels, 2004). Hannover and Kessels (2004) showed that the prototypical student who prefers stereotypically female subjects such as humanities to stereotypically male subjects such as physics is perceived in a more positive manner than a student who prefers science subjects. Additionally, perceived similarity to other members of a field moderates women's interest in continuing in a stereotypically male domain (Cheryan and Plaut, 2010). Therefore, women in science face a high hurdle when intending to stay in this male environment because science appears rather male and unpopular. The stereotypes contradict their fit to the field and encourage women to leave.

Nevertheless, several women master this hurdle and begin to pursue science. Science competitions provide one opportunity for interested students to engage in science domains outside of school. In Germany, 9,065 students participated in in the 2019 Science Olympiads, which include competitions in several science domains.

Yet, gender differences are visible and especially pronounced in the German Physics Olympiad. The German Physics Olympiad is organized into four consecutive rounds. Each round requires students to solve physics tasks or do experiments. The initial registration for the competition is open to any interested student, who is still in school and within the yearly set age limit. In the first round, physics teachers receive a best practice solution for the tasks and judge the participants' solution according to this. Only those participants, who solved the tasks best, continue from there on to the next rounds. Thus, the number of participants continually decreases. Eventually, the best five students form the national team for the international competition. The Physics Olympiad faces two connected problems concerning gender representation. First, fewer females than males choose to participate. In 2018, only 28% of all participants were female. Second, these female participants drop out of the competition in disproportionally higher numbers than the male participants do. This often leads to all-male national teams, as was the case in 2019.

Stereotype threat and social identity threat

What causes this underrepresentation of female participants? An important factor in the context of science competitions is stereotypes (Steegh et al., 2019). Stereotype threat theory explains how stereotypes impact behavior.

Stereotype threat occurs to minority groups that enter a field in which they are underrepresented and faced with negative stereotypes about their groups' characteristics or abilities (e.g., Hall et al., 2015; Bedyńska et al., 2018). It is hypothesized that the negative stereotypes trigger stereotype threat, which inhibits the members of the stereotyped group from performing to their full potential (e.g., Steele and Aronson, 1995; Steele et al., 2002). Implicit and explicit cues in the environment about the stereotypes' eligibility can induce this mechanism (e.g., Spencer et al., 1999; Marchand and Taasobshirazi, 2013).

Stereotype threat effects have been demonstrated for several groups, from women in sciences (e.g., Miller et al., 2015; Smyth and Nosek, 2015), to males in typically female jobs, to older employees in working life (e.g., Hartley and Sutton, 2013; Froehlich et al., 2016; Kalokerinos et al., 2017; Rahn et al., 2020). All of these groups face stereotypes regarding either their abilities or their lacking fit within their chosen environment, e.g., that women lack talent for science and are consequently not able to perform as good as men. Negative stereotypes lead not just to lower performance levels (Steele and Aronson, 1995; Shih et al., 1999; Flore and Wicherts, 2015) but also to various other negative changes such as the minority members' stronger wishes to leave the environment (Kalokerinos et al., 2017).

Although women try to counteract the negative stereotypes in science to prove their falsehood (Jamieson and Harkins, 2011), they still feel less accepted, more mentally exhausted, and less competent (Schmader and Johns, 2003; Hall et al., 2015). Stereotype threat is also connected to heightened anxiety (Ben-Zeev et al., 2005) and burnout (Hall et al., 2018).

Social identity threat intensifies negative effects even further (see van Veelen et al., 2019). Stereotype threat is a specific theory within the theoretical framework of social identity threat (Schmader et al., 2015). The general feeling of being different from the majority group because of one's social identity causes social identity threat (e.g., Steele et al., 2002; Hall et al., 2018). Schmader (2002) showed that gender identification can explain performance differences between males and females in science. Women who strongly identified with their gender performed tasks worse than men if the tasks were linked to gender identity. Women with lower gender identification performed at the same level as men. As women identify with the negatively stereotyped gender identity more easily when in science environments (Marx et al., 2005), gender identification can lead to stereotype threat and, consequently, lower performance (e.g., Shih et al., 1999; Flore and Wicherts, 2015). Endorsing negative stereotypes and believing in their eligibility further heightens these effects (Schmader et al., 2004).

Sense of belonging

Stereotypes about females in physics also go beyond stereotype threat. Members of a stereotyped group that enter a situation in which stereotypes are present then doubt their abilities and are more likely to interpret lower performance as the result of missing fit within the environment (Aronson and Inzlicht, 2004). When doubting their abilities, individuals perceive features in the environment that could justify their doubt. Belonging uncertainty — the feeling of not being sure whether they fit within the group (Walton and Cohen, 2007) — can lead to individuals distancing themselves from the group, environment, and tasks. For example, female students who perceive their environment as negatively stereotyping women in math feel less belonging within the math environment (Good et al., 2012). This can lead to negative performance and, thereby, to the unintentional confirmation of the negative stereotypes (Steele and Aronson, 1995).

Sense of belonging, which is the feeling of connection, membership, trust, participation, positive affect, and acceptance in a group (Good et al., 2012), is closely connected to a wide range of variables relevant for academic success. Among others, value of school (Gillen-O'Neel and Fuligni, 2013), intrinsic motivation (Freeman et al., 2007), and academic adjustment in college (Pittman and Richmond, 2007) are linked to belonging. Consequently, belonging uncertainty is especially disadvantageous in situations that require high performance and achievements.

Women could benefit from feeling more belonging in science. Murphy et al. (2007) showed that women had lower sense of belonging and fewer intentions to participate in science settings that appeared to be predominantly male than in settings with equal numbers of male and female participants. Because men choose science environments more often, they create a predominantly male environment that is associated with male characteristics. Thus, as the sense of belonging influences a woman's decision to leave science or not (e.g., Good et al., 2012; Banchefsky et al., 2019), the association of male characteristics with science is likely to reduce women's aspirations to continue in science fields (e.g., Makarova et al., 2019).

Interventions against stereotype threat

To interrupt the ongoing cycle of stereotype threat and self-selection out of science, a supportive identity and system of values need to be formed; these are predictors of persistence in a domain (Estrada et al., 2011). Especially short psychological interventions that can be implemented easily in various situations (e.g., Yeager et al., 2013; Brady et al., 2020) can be valuable because they can be implemented in school, college and even in physics competitions. Growth mindset and value affirmation interventions both fall into this category and have been shown to be beneficial in protecting participants against stereotype threat and social identity threat.

Growth mindset

One common stereotype is that females do not have science talent. Especially in sciences that require a lot of mathematics such as physics, people endorse the opinion that success is built on talent (Deiglmayr et al., 2019; see also Archer et al., 2020; Johansson, 2020). This, however, results in a vicious cycle: Fewer women in a field are connected to higher beliefs in talent as the basis for success in this domain (Bailey et al., 2019). As stereotypes drive women to leave physics, the predominantly male gender ratio persists and consequently strengthens the stereotypes about female talent, which again drives more women to leave.

How can an intervention break this cycle? Aiming to change implicit theories of intelligence takes away the basis of the assumption that talent is essential for success.

Implicit theories of intelligence can be divided into two groups: Entity theories, which assume that characteristics such as cognitive abilities cannot be changed, and incremental theories, which assume those characteristics change through effort and work (e.g., Blackwell et al., 2007; Burnette et al., 2013). Entity theories of intelligence tend to promote stereotypes about talent in science. Yeager et al. (2016) tested growth mindset interventions that promoted an incremental theory of intelligence. These interventions had three successive steps: First, participants read information on how intelligence can be enhanced. Second, they found examples in their personal experience where the learned information applied and, lastly, they wrote a letter that encouraged other students to handle struggles based on this information. Students' belief changed from an entity theory to an incremental theory of intelligence after the intervention.

Also, stereotypes affected the performance of college students less after such interventions (e.g., Alter et al., 2010), thus showing reduced stereotype threat. Students who held an incremental theory of intelligence also enjoyed and engaged more in academic work (Aronson et al., 2002).

Values affirmation

Female students who enter a physics environment are perceived as a minority whose fit and belonging are threatened and questioned (e.g., Aronson and Inzlicht, 2004). This uncertainty can be reduced with values affirmation interventions that heighten the fit of self and situation (e.g., Cohen et al., 2006). Cohen et al. (2006) asked a stereotypically threatened minority to participate in a values affirmation intervention that aimed to achieve self-integrity and an unthreatening environment. Students received a list of values and were asked to choose the personally most important one and write about why it was important to them. Their results showed that the achievement gap, created by racial stereotypes, went down by 40% after the intervention. The activation of stereotypes in performance situations was also lowered. Similar effects were shown by Cohen et al. (2009) along with the intervention's long-term positive impact on performance. Nevertheless, several studies find no effects of the interventions (de Jong et al., 2016; Bayly and Bumpus, 2019) or even goal disengagement (Vohs et al., 2013). Still, in physics contexts, Miyake et al. (2010) found beneficial effects for women, especially if these endorsed stereotypes about women in science.

The present study

How are females in physics affected by stereotypes and how can we help them pursue their interest in physics? To address these questions, the current study aimed to analyze two different interventions against stereotype threat in the context of the German Physics Olympiad. The results of previous research suggest that brief growth mindset and values affirmation interventions are useful in combating stereotype threat for school (e.g., Cohen et al., 2009; Yeager et al., 2016) and college students (e.g., Aronson et al., 2002; Miyake et al., 2010). However, to the best of our knowledge, these interventions have not been tested in science competitions.

The Physics Olympiad presents a typically predominantly male science environment, while at the same time presenting a selective sample of participants who have shown ongoing interest in science by entering the competition and pursuing physics knowledge beyond school education. Although the competition does not explicitly broadcast stereotypes about women having lacking talent for science, previous research has indicated that stereotype threat has negative effects on female participants of science competitions (e.g., Steegh et al., 2019; Ladewig et al., 2020). It seems advisable to implement growth mindset and values affirmation interventions to protect female participants of the German Physics Olympiad from the potential damage by those stereotypes. Implementing the interventions during the participants' first encounter with other Physics Olympiad participants enables the assessment of whether these interventions prevent stereotype threat because it marks female students' first exposure to the predominantly male environment. The encounter should heighten stereotype threat and social identity threat effects as here, female participants are first personally entering the apparently stereotyping and predominantly male environment of the competition. Researching both participants' personal agreement with stereotypes and their perception of other's beliefs in stereotypes within the Physics Olympiad seems advisable.

Based on previous research on stereotype threat, social identity threat, and sense of belonging, we formed several hypotheses. The first hypothesis focused on the benefits of the interventions on the variables that stereotype threat and social identity threat are theorized to impact. We assumed that both interventions would have equally beneficial effects but that the best results would be achieved by combining the two interventions. Those effects were expected to continue after the seminar. As, however, we do not expect male participants to suffer under any social identity or stereotype threat effects, which the interventions aim to counteract, they should also not experience changes by participating in the interventions.

> *H1a*: We hypothesized that female students would rate sense of belonging higher and gender identification lower directly after the interventions as well as several weeks after the interventions than before the interventions. For male students, no changes were expected.
>
> *H1b*: We expected that the combination of both interventions would have stronger effects, that is, would lead to a stronger increase in sense of belonging and a stronger decrease in gender identification.

Further, we aimed to compare the female and male participants' assessments of variables crucial for stereotype threat and for perceived social identity threat with the study. Therefore, the second hypothesis can be split into three parts based on the environment the participants were facing. At the first measurement point, students had not yet met the other participants and made their assessments based on previously experienced physics environments. These perceptions were expected to be stereotyped on the basis of participants' experience from school and media. This study used an explicit measure of stereotype endorsement; it needs to be considered that the assessments, especially those of the female participants, might differ from implicit measures (*cf.* Kessels et al., 2006). Women might feel less inclined to explicitly agree with negative stereotypes about women in science than male participants do and might indicate lower beliefs in negative stereotypes about women. An explicit measure seems, nevertheless, appropriate as higher stereotype endorsement was previously shown to predict higher sensitivity to the consequences of stereotype threat (e.g., Schmader et al., 2004; Pennington et al., 2016).

> *H2a*: We hypothesized that, before the interventions, females would endorse negative stereotypes about women in physics less than males. Here, female should perceive more social identity threat than males.

When the participants arrived at the seminar, they encountered a predominantly male group. This again should present a stereotypical environment. The literature suggests that in predominantly male science groups, females identify more with their gender (e.g., Schmader, 2002) while also feeling less belonging and perceiving the environment to be stereotyping (e.g., Good et al., 2012).

> *H2b*: We hypothesized that, after the first meeting with other participants of the German Physics Olympiad, females would perceive stronger environmental stereotyping than males. We expected females to endorse negative stereotypes about women in physics less than males.

The interventions took place in the seminars. The interventions aimed to reduce perceptions of stereotyping for the female participants but not for the male participants and we thus did not expect women to perceive stereotypical cues in the environment differently than the male participants.

> *H2c*: We hypothesized that, directly after the interventions, females would have equal perceptions of environmental stereotyping and social identity threat to males in the physics environment. We expected females to endorse negative stereotypes about women in physics less than males.

Materials and methods

To study the hypotheses, we conducted a study within two successive years of the German Physics Olympiad.

Project "Identiphy – Identity development in physics!"

The study presented in this paper was part of the larger project "Identiphy – Identity development in physics!" (see also Ladewig et al., 2022). The project included a longitudinal study with two cohorts of German Physics Olympiad participants. Participation was voluntary. The study included four measurement points that took place before and after a weekend-long seminar, which was advertised to teach additional physics knowledge and give participants the chance to meet other participants of the German Physics Olympiad. The study took place directly after the first competition round, which consisted of solving physics tasks at home, so students encountered other participants for the first time at the seminars. Thereby, we aimed to study the regular competition conditions: Students, most often, encounter other highly interested and talented students for the first time when entering the higher competition's rounds. This was replicated with our placing of the study after filling in the first tasks at home. Also, we did not explicitly trigger stereotypes. In a normal competition, this would also not happen. Students just perceive the regular broadcasting of the stereotypes in the competition and environment.

Participants

All participants in the German Physics Olympiad received an invitation to participate in voluntary weekend seminars. Invitations went out *via* e-mail or letter, and participants were informed that declining participation would not lead to any disadvantages in the competition and that questionnaires would remain anonymous. All students or, if they were underaged, their legal guardians provided informed consent before participation.

Overall, 298 students participated. Of these, 82 were female (age: $M = 15.87$, $SD = 1.22$) and 216 male (age: $M = 15.93$, $SD = 1.36$). 167 students participated in the first (age: $M = 15.87$, $SD = 1.26$; 42 female, 125 male) and 131 in the second cohort (age: $M = 15.95$, $SD = 1.40$; 40 female, 91 male participants). Students could choose one out of six weekend seminars in the first year and one out of four weekend seminars in the second year. At the weekend seminars, participants formed 11 groups in the first and 10 groups in the second year. Each group was randomly assigned to an intervention approach. In each case, the whole group was assigned to one approach because each intervention demanded different amounts of time and could only be easily included in the program if all students within one group participated in the same intervention. Table 1 shows the numbers of participants in each intervention method for both years and the overall sample, who were included in the analyses based on the intervention groups they could be clearly associated with.

We deferred from separating the cohorts in the analysis because they did not vary significantly in gender

$$\chi^2[1] = 1.13,\ p = 0.287$$

or age

$$t[264] = -0.51,\ p = 0.609.$$

Using G*Power 3.1 (Faul et al., 2007, 2009) to calculate a sensitivity analysis, the sample size of 278 participants, whose assessments were clearly allotted to the three intervention groups, has a critical population effect size of 0.08 for comparing two groups, in this case male and female participants, for an analysis of variance. The sample size of 278 participants has a critical population effect size of 0.10 for comparing three groups with a mixed analysis of variance.

Procedure and intervention methods

Figure 1 gives an overview of the study proceedings and the scales. Students were able to choose one of the four cities in which the seminar took place according to their own preferences. Students registered for the seminar and received further information on the study as well as informed consent forms. Following the submission of those forms, students filled in a questionnaire online and received preparatory materials covering the physics content of the seminar.

Students arrived at the seminars without having knowledge of the planned intervention. They were first assigned to groups before filling in the second questionnaire. Next, the interventions took place. At the seminar, these questionnaires and interventions took place on paper under supervision of the seminar staff.

The growth mindset intervention was adapted from Yeager et al. (2016). Participants read a text that explained how learning changes the brain, how to improve performance, and how to handle struggles. Participants repeated the taught information by answering two questions about the text's content before writing about a personal experience where this information could be or had been used. The writing task was not limited in length.

The values affirmation intervention was adapted from Cohen et al. (2006). Participants chose one value from a list of 13 (e.g., "my family and friends," "being intelligent") and explained its importance and meaning for their life and possibly for their interest in physics. The writing task was not limited in length.

In both interventions, we did not study the students' results of the writing task. We wanted the students to feel free to write anything personal without feeling hindered by knowing someone else would read it.

Every student participated in an intervention. We thus assumed stereotype threat in the sample as previous research has shown that female participants in science competitions suffer under negative stereotypes (e.g., Steegh et al., 2020). No untreated group was implemented, which is why we can only compare the differences between the intervention methods. Thereby, we also wanted to ensure that every student had the chance to benefit from an intervention as stereotype threat, based on previous literature, is to be expected within the whole sample.

At the end of the second seminar day, students again filled in a questionnaire. Approximately 6 and 12 weeks after the seminar students were given the chance to do further physics tasks, which recaptured the seminar contents, and to receive feedback on their solutions. The feedback was focused on the way the students were able to apply the seminars' new physics content on other physics task. Thereby, the feedback was written as a positive support to further use the new knowledge, while still pointing out where mistakes were made and how to further improve in applying the knowledge. Subsequently, students were asked to fill in the last questionnaire online.

TABLE 1 Demographic data of the participants, split by intervention groups.

			Cohort 1	Cohort 2	Overall sample
Growth mindset	Age	*M* (*SD*)	15.96 (1.29)	16.35 (1.23)	16.13 (1.22)
	Gender	*N* male/female	50 (37/13)	37 (25/12)	87 (63/25)
Values affirmation	Age	*M* (*SD*)	15.92 (1.32)	15.73 (1.53)	15.84 (1.41)
	Gender	*N* male/female	38 (31/7)	30 (22/8)	68 (53/15)
Combination	Age	*M* (*SD*)	15.76 (1.28)	15.85 (1.38)	15.80 (1.33)
	Gender	*N* male/female	70 (51/19)	53 (35/17)	123 (86/36)

Measures

The questionnaires included five scales, which were used for the analyses.

Sense of belonging

Sense of belonging was measured on a scale adapted from Good et al.'s (2012) Math Sense of Belonging scale. All 30 items were ranked from 1 (*strongly disagree*) to 5 (*strongly agree*). In the first and last questionnaires, all items referenced the group of the participants' school physics class (e.g., "When I am in my physics lessons, I feel that I belong to the group."; first questionnaire: Cronbach's $\alpha = 0.63$; last questionnaire: Cronbach's $\alpha = 0.94$),

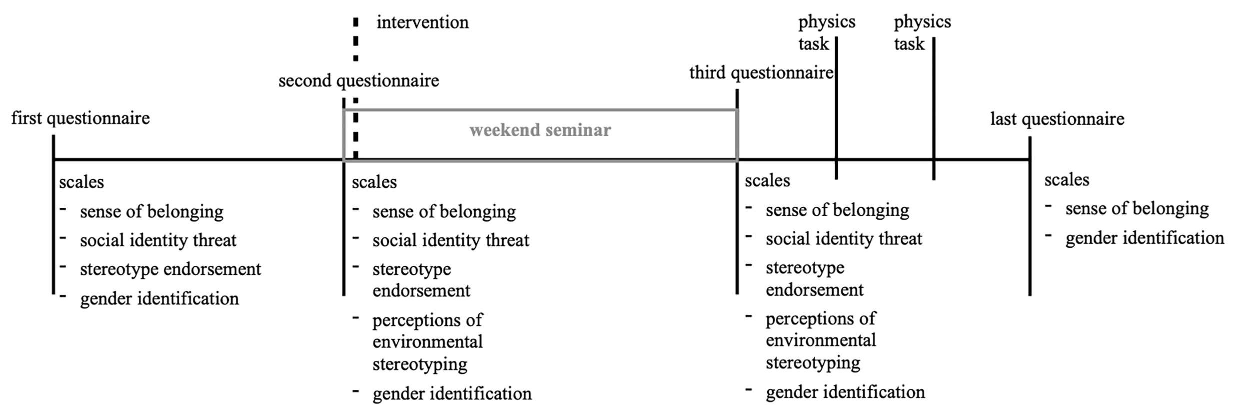

FIGURE 1
Graphical depiction of the study proceedings including the scales, which were used for the analyses.

whereas, upon arrival at the weekend seminar, the seminar group was the reference group for the first impression (e.g., "At the moment, I feel that I belong to the seminar group."; Cronbach's $\alpha = 0.91$) and at the end of the seminar (e.g., "During the weekend seminar, I feel that I belong to the group."; Cronbach's $\alpha = 0.91$).

The questionnaire consisted of five subscales measuring trust, acceptance, negative affect (reverse coded), desire to fade (reverse coded), and membership. As suggested by the authors of the scale (Good et al., 2012), we used the scale without splitting it further into subscales.

Social identity threat

Social identity threat was measured with a scale adapted from Rattan et al. (2018), which is itself an adapted version of a scale from Steele and Aronson (1995). The scale consists of four items (e.g., "My gender influences the perception that others have of my physics abilities"). The items were assessed on a scale ranging from 1 (*Not at all*) to 5 (*Extremely*). High values on this scale indicate high social identity threat. Cronbach's alpha was 0.82 in the first questionnaire, 0.80 at the beginning of the seminar, and 0.76 at the end of the seminar.

Stereotype endorsement

Stereotype endorsement was measured with a scale by Schmader et al. (2004) consisting of three items, which were adapted to physics (e.g., "It is possible that men have greater physics ability than women do."). Items were ranked from 1 (*strongly disagree*) to 5 (*strongly agree*). High values indicate high stereotype endorsement. Cronbach's alpha was 0.71 in the first questionnaire, 0.69 at the beginning of the seminar, and 0.69 at the end of the seminar.

Perceptions of environmental stereotyping

Perceptions of environmental stereotyping were measured with a shortened 4-item version of a scale by Good et al. (2012), which is an adapted version of a scale by Fennema and Sherman (1976). Items (e.g., "The other students in my seminar group believe that men are naturally better in physics than women.") were ranked from 1 (*I do not agree*) to 5 (*I agree*). Cronbach's alpha was 0.81 at the beginning and 0.82 at the end of the seminar.

Gender identification

Gender identification was measured with four items from a scale by Schmader (2002), which is an adapted version of a scale by Luhtanen and Crocker (1992). Items (e.g., "Being a male/female is important for the perception I have of myself.") were ranked from 1 (*strongly disagree*) to 5 (*strongly agree*). Cronbach's alpha ranged between 0.80 (first questionnaire), 0.83 (beginning of seminar), 0.83 (end of seminar), and 0.87 (last questionnaire).

Growth mindset

A scale to assess students' growth mindset was included in the study but not further for the here mentioned analyses. The scale was based on a scale by Dweck (2000). The data for the intervention group, which was supposed to achieve a growth mindset, showed high values previous to the intervention in the first questionnaire ($M_{male} = 3.68$, $SD = 0.48$; $M_{female} = 3.67$, $SD = 0.47$) and very high values in the last questionnaire after the interventions ($M_{male} = 4.16$, $SD = 0.83$; $M_{female} = 4.15$, SD = 0.76).

Results

The analyses were, first, focusing on the effects of the interventions, and, second, on the gender differences in stereotype threat and social identity threat.

Effects of the interventions

With regard to Hypotheses 1a and 1b, a mixed analysis of variance was calculated in SPSS (version 26, IBM Corp., 2015) for sense of belonging and gender identity across all four measurement points. The means and standard deviations can be found in Table 2 for sense of belonging and in Table 3 for gender identity.

First, a significant main effect of measurement point was found on belonging, $F(3, 471) = 379.34$, $p < 0.001$, but not on gender identification, $F(3, 471) = 0.46$, $p = 0.713$. There was no significant main effect of gender on either belonging, $F(1, 157) = 1.34$, $p = 0.249$, or gender identification, $F(1, 157) = 0.16$, $p = 0.695$. There was also no significant main effect of the intervention group on belonging, $F(2, 157) = 1.36$, $p = 0.259$, or on gender identification, $F(2, 157) = 0.39$, $p = 0.681$. These results only partly support Hypothesis 1a by showing changes in sense of belonging but no gender differential effect on either variables or changes over time for gender identification.

Hypothesis 1b is also not supported by these results as the intervention groups did not differ. Looking more closely, the interaction term gender x intervention group did not have a significant effect on belonging, $F(2, 157) = 0.55$, $p = 0.578$, or on gender identification, $F(2, 157) = 0.036$, $p = 0.965$. The further interaction term measurement point × gender also did not show a significant effect on belonging, $F(3, 471) = 1.89$, $p = 0.131$, or on gender identification, $F(3, 471) = 0.50$, $p = 0.685$, indicating no significant differences between the changes in the groups along the measurement points. The third interaction term measurement point x intervention group showed a significant effect on belonging, $F(6, 471) = 2.97$, $p = 0.008$, but not on gender identification, $F(6, 471) = 0.91$, $p = 0.486$. The interaction term measurement point x gender x intervention group did not show a significant effect on belonging, $F(6, 471) = 0.467$, $p = 0.828$, or on gender identification, $F(6, 471) = 1.21$, $p = 0.301$, indicating that all groups experienced the study similarly.

Gender differences in stereotype threat and social identity threat

To test Hypotheses 2a, b, and c, analyses of variance were calculated for each measurement point to compare the assessments of male and female participants and the assessments between the intervention groups. The means and standard deviations, split by gender and intervention group, can be found in Table 4.

Hypothesis 2a focused on the first measurement point. Our results show a significant main effect of gender on social identity threat, $F(1, 259) = 15.53$, $p < 0.001$, but not on stereotype endorsement, $F(1, 259) = 3.56$, $p = 0.060$. The intervention group did not have a significant main effect on either social identity threat, $F(2, 259) = 1.49$, $p = 0.227$, or stereotype endorsement, $F(2, 259) = 0.17$, $p = 0.842$, nor did the interaction term gender × intervention group prove significant for social identity threat, $F(2, 259) = 0.09$, $p = 0.916$, or stereotype endorsement, $F(2, 259) = 1.01$, $p = 0.367$. The results indicate a confirmation of the hypothesis regarding social identity threat, which was rated significantly higher by females than males.

Next, Hypothesis 2b targeted the measurement point at the beginning of the first seminar day. Our results show a significant main effect of gender on social identity threat, $F(1, 268) = 9.39$, $p = 0.002$, but not on stereotype endorsement, $F(1, 268) = 1.56$, $p = 0.213$, or on perceptions of environmental stereotyping, $F(1, 268) = 2.74$, $p = 0.099$. The intervention group did not have a significant main effect on social identity threat, $F(2, 268) = 0.76$, $p = 0.467$, stereotype endorsement, $F(2, 268) = 0.46$, $p = 0.629$, or perceptions of environmental stereotyping, $F(2, 268) = 0.12$, $p = 0.988$. Lastly, the interaction term gender x intervention group also did not prove to be significant for social identity threat, $F(2, 268) = 0.18$, $p = 0.836$, stereotype endorsement, $F(2, 268) = 0.16$, $p = 0.852$, or perceptions of environmental stereotyping, $F(2, 268) = 0.43$, $p = 0.653$. Again, these results mostly contradict the hypothesis, while the results for social identity threat — with a higher mean for females — confirm it.

Finally, Hypothesis 2c assumed changes would occur in the assessment of the variables due to the interventions, which is at the third measurement point. Again, a significant main effect of gender was found on social identity threat, $F(1, 267) = 6.63$, $p = 0.011$, but not stereotype endorsement, $F(1, 267) = 3.28$, $p = 0.071$, or perceptions of environmental stereotyping, $F(1, 267) = 0.15$, $p = 0.703$. The intervention group did not have a significant main effect on social identity threat, $F(2, 267) = 0.53$,

TABLE 2 Means and standard deviations of sense of belonging for all measurement points, split by gender and intervention method.

	Growth mindset				Values affirmation				Combination			
	Boys		Girls		Boys		Girls		Boys		Girls	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
First assessment point	3.14	0.19	3.07	0.18	3.07	0.14	3.08	0.21	3.08	0.19	3.07	0.21
Second assessment point	4.33	0.42	4.16	0.54	4.13	0.44	4.13	0.42	4.36	0.4	4.43	0.29
Third assessment point	4.52	0.38	4.41	0.41	4.26	0.59	4.36	0.39	4.41	0.39	4.45	0.45
Fourth assessment point	4.3	0.4	4.14	0.54	4.18	0.6	4.02	0.42	4.13	0.53	3.92	0.47

TABLE 3 Means and standard deviations of gender identification for all measurement points, split by gender and intervention method.

	Growth mindset				Values affirmation					Combination		
	Boys		Girls		Boys		Girls			Boys	Girls	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
First assessment point	2.88	1.23	2.79	1.03	2.56	0.77	2.85	1.11	2.64	0.91	2.4	0.85
Second assessment point	2.8	1.14	2.92	1	2.54	1.07	2.58	0.9	2.5	1.16	2.83	1.19
Third assessment point	2.59	1.28	2.67	1.02	2.55	1.02	2.6	1.3	2.47	1.07	2.76	1.31
Fourth assessment point	2.76	1.19	2.78	1.17	2.47	1.34	2.63	1.35	2.69	1.08	2.59	1.07

TABLE 4 Means and standard deviations of perceived social identity threat, stereotype endorsement, and perceptions of environmental stereotyping for the first three measurement points, split by gender and intervention group.

		Growth mindset				Values affirmation				Combination			
		Boys		Girls		Boys		Girls		Boys		Girls	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Social identity threat	First assessment point	1.7	0.82	2.23	0.85	1.5	0.71	1.92	1.02	1.59	0.74	2.03	1.01
	Second assessment point	1.75	0.84	2	0.69	1.58	0.67	1.98	1.01	1.77	0.76	2.11	0.87
	Third assessment point	1.77	0.87	2.02	0.61	1.8	0.86	2.14	1.03	1.84	0.81	2.18	0.92
Stereotype endorse-ment	First assessment point	2.19	1.08	1.79	0.81	2.07	0.94	2.11	0.83	2.26	1.02	1.84	0.8
	Second assessment point	2.12	1.05	1.85	0.98	2.15	0.99	2.09	0.86	2.22	1	2.03	0.94
	Third assessment point	2.18	1.07	1.88	0.96	2.31	1.12	2.12	1.05	2.4	1.05	2.04	0.98
Perceptions of environ-mental stereo-typing	Second assessment point	1.67	0.72	2	0.91	1.75	0.74	1.88	1	1.77	0.78	1.88	0.89
	Third assessment point	1.68	0.8	2.13	0.88	1.95	0.95	1.7	0.87	1.74	0.81	1.74	0.89

$p = 0.589$, on stereotype endorsement, $F(2, 267) = 0.67$, $p = 0.514$, or on perceptions of environmental stereotyping, $F(2, 267) = 0.55$, $p = 0.580$. The same result was found for the interaction term gender x intervention group, with no significant effect found on either social identity threat, $F(2, 267) = 0.14$, $p = 0.873$, stereotype endorsement, $F(2, 267) = 0.09$, $p = 0.917$, or perceptions of environmental stereotyping, $F(2, 267) = 1.91$, $p = 0.150$. Whereas the results regarding environmental stereotyping and stereotype endorsement confirm the hypothesis, the results regarding social identity threat contradict it.

Discussion

What can be done to reduce the gender gap in participation in the German Physics Olympiad? This question was addressed in the present study. We tested a growth mindset and a values affirmation intervention as well as a combination of both interventions regarding their impact on the assumed stereotype threat and social identity threat for females in the competition. We assumed that female participants suffered from social identity threat, which was hypothesized to be expressed in higher perceived social identity threat and stereotype endorsement, as well as from stereotype threat, which was expected to be seen in higher stereotype endorsement. We, nevertheless, expected females and males to rate sense of belonging and gender identification to a similarly high degree after the interventions.

This expectation was partially fulfilled. Females did not appear to be negatively impacted due to stereotype endorsement or perceived social identity threat after the interventions: female contestants rated their perceived social identity threat higher than male contestants did at the beginning of the study, and this was still the case after the interventions, even though it had been expected that the interventions would reduce social identity threat. Therefore, we did not find any changes in assessments due to the interventions. Likewise, none of the groups showed higher impact. Females' assessment of sense of belonging, gender identification, stereotype endorsement, and perceptions of environmental stereotyping did not vary before or directly after the interventions; several weeks after the interventions, female contestants' sense of belonging was lower than that of males. This contradicts the assumption of both a social identity threat and a stereotype threat, suggesting that the interventions hindered these — all in similarly effective ways, with no one type of intervention being more advantageous than the others.

Nevertheless, it needs to be mentioned that prior to the interventions, the highly selective sample of female participants apparently did not differ from the male participants on the decisive variables: Females and males who participated in the study were similar in their assessments of the used scales Noticeably, female participants did not appear to suffer under either stereotype threat or social identity threat effects.

No stereotype threat or social identity threat?

The results of this study seem to indicate that this highly selective sample is at least not hindered or harmed by stereotype or social identity threat effects either before or after the interventions; this contradicts previous findings on stereotypes. However, we cannot say if these effects would be comparable without interventions, as we did not include a control group.

First, although we expected females to suffer under threats while participating in the predominantly male physics seminars (see, e.g., Marx et al., 2005; Good et al., 2012; Schmader et al., 2015), our results suggest that the interventions prevented this. Even though we did not find any reduction in the effects of stereotype threat after the interventions, the interventions seemed to help the females to not fall behind in sense of belonging, which could have been expected without interventions based on social identity and stereotype threat theory (see, e.g., Aronson and Inzlicht, 2004; Murphy et al., 2007). Participating in the interventions apparently prevented a split between the genders. Even though we cannot draw the conclusion that the interventions reduced any of the negative effects, we can assume that the interventions prevented the effects from appearing in the first place.

Second, there could be several different reasons for the results we found. Female participants in the German Physics Olympiad are a specific sample. They have mastered several hurdles to compete in the competition: They have resisted rejecting cues in a stereotypically male domain and have not shied away from a competition rarely won by females. Entering the competition can already be seen as an indicator of high resistance (e.g., Gonsalves et al., 2021) to negative stereotypes, male predominance, and to associations of physics with the male gender, which indicate less fit and reduce sense of belonging and cause women to leave physics (see, e.g., Cheryan and Plaut, 2010; Makarova et al., 2019). Nevertheless, several studies showed that females in science competitions suffer under stereotypes (see, e.g., Steegh et al., 2019).

Why was the sample of this study even more resilient?

This study was tied to participation in a weekend seminar. Participants were willing to spend a whole weekend in a group of interested and talented students (see Höffler et al., 2019), solving physics tasks and conducting experiments. The group thus most likely consisted of female students who had even more interest and wanted to deepen their knowledge in physics even more than other participants of the Physics Olympiad. As all 539 female participants of the two cohorts of the German Physics Olympiad could have participated in this study but only 82 did, our sample possibly was more engaged in the field and, therefore, more resistant to cues that hinder females from pursuing science.

Further, our sample might vary in motivational profiles and success expectations for proceeding to the competition's next round to the overall group of participants (see Steegh et al., 2021). The weekend seminars took place after the end of the first round but before the announcement of the participants who would continue to the next round. It could be assumed that the participants of our study chose to be in the seminars either in expected preparation for the continuing competition or just to engage further in physics (see Höffler et al., 2019). This would imply higher interest, higher learning goal orientation, and a higher self-concept (see Höffler et al., 2017) than the average participant — factors that could interact with an individual's susceptibility to stereotype or social identity threat.

Stereotype threat theory apparently does not apply to this group of participants. Thus, other factors that might account for the gender ratio and the achievement differences in this field need to be considered. Previous studies have suggested further starting points, which can be separated into two main groups with regard to their implications for science competitions.

First, possible causes might be found in the differences between the best contestants' characteristics and characteristics of females, who are highly interested but not as successful (see also the competition proceedings; e.g., Petersen and Wulff, 2017): Two questions are interesting here: First, in which characteristics or abilities are these contestants especially advanced? Differences between male and female participants that may cause gender differences and be relevant for success in the competition might regard self-concept (see, e.g., Saß and Kampa, 2019; Vinni-Laakso et al., 2019), competence (see, e.g., Schorr, 2019), or parental support (see, e.g., Hoferichter and Raufelder, 2019; Schorr, 2019). These variables have been found to closely align with gender differences and the achievement gap. Second, do personal characteristics vary between the best contestants and the female participants who drop out of the competition earlier? It appears useful to look closely at empathy (see Ghazy et al., 2019), motivation (see, e.g., Watt et al., 2019; Luttenberger et al., 2019a; Dietrich and Lazarides, 2019), and interest (see, e.g., Ertl and Hartmann, 2019; Song et al., 2019); these variables are closely related to persistence in science and to gender differences. Analyzing differences in these variables between male and female participants might give insights into the personal characteristics that hinder talented young women from succeeding to the finale.

Further research should also analyze the competition regarding success factors that are independent of the contestants' personal characteristics: Do tasks and experiments especially favor male participants (see, e.g., Sanchis-Segura et al., 2018)? Is the content of tasks (see, e.g., Wille et al., 2018; Wheeler and Blanchard, 2019) or the context of the examination process more disadvantageous for females (e.g., Sobieraj and Krämer, 2019)? Studying those factors could help make the competition more equitable for both genders.

However, it might also be a possibility that the general effect of stereotypes on females in science — in our case physics — is changing. Younger generations could perceive the world as being more equal thus suffering less under stereotypes. The fact that the rates of girls dropping out of the competition is higher than the boys', could, for example, just be out of a lack of personal importance of investing into succeeding in the competition. Which are the personal advantages that girls gain out of competing — aside from, e.g., knowledge and getting to know other interested students? Are girls and boys perceiving investing time and studying for the competition as justifiable for their personal outcome? Future research is thus not just asked to focus on the impact of changing perceptions of gender and societal issues, which are likely to impact feelings and perceptions of equality in our societies, but also on gender difference in the significance attributed to science.

Limitations

First, all participants in the German Physics Olympiad received invitations to the study. However, participation was voluntary and we cannot assume that this sample is representative of the overall sample of contestants. Rather, we assume the participants of our study to be more interested, engaged, and more likely to continue in science than the other contestants. For this highly selective sample, which is most likely to pursue a career in physics, the theory of stereotype or social identity threat apparently does not suffice as an explanation for the gender gap. Future research should apply new theories to find more useful explanatory approaches.

Second, stereotype threat was measured explicitly in this study by measuring stereotype endorsement. Participants were asked how much they agree with common derogatory stereotypes about females' physics abilities. Previous research showed higher stereotype endorsement as a predictor of higher susceptibility to stereotype threat (e.g., Schmader et al., 2004; Pennington et al., 2016). We considered our explicit method as preferential to activating stereotypes or implicitly measuring participants' agreement with stereotypes, as the weekend seminar depicted the regular environment of the competition and the measurement was combined within the questionnaires without drawing any special attention to its purpose. Nevertheless, explicitly measuring stereotype endorsement might lead to divergent results, although previous research is not congruous (see, e.g., Kessels et al., 2006). As the assessments of stereotype endorsement were equally high throughout the study, we do not believe that our results are biased. Regardless, future research should add an implicit measure to control for social desirability effects.

Lastly, our study did not use a control group. We can thus only assume that finding no differences between male and female participants' assessments after the interventions indicates beneficial effects of the interventions on stereotype and social identity threat. This seems the appropriate conclusion as previous literature rather consistently showed the existence of stereotype threat for females in science competitions. Nevertheless, future research should include a control group to measure the extent of the interventions' effects.

Conclusion

This study addressed factors that are potentially responsible for male predominance in the German Physics Olympiad. Previous research showed that stereotype and social identity threat are useful models to explain the underachievement and consequent underrepresentation of women and females in science. The results of this study, however, suggest that stereotype threat and social identity threat are possibly not applicable to the highly interested and engaged female participants of the German Physics Olympiad. From the beginning, females who chose to participate in the competition and in the study's weekend seminars were not affected more negatively by stereotypes or social identity threat than their male counterparts. It thus seems that the commonly expected harm done by stereotypes did not occur to the extent expected. Nevertheless, further pursuing to include interventions against stereotype threat in environments, which are highly likely to induce the mechanism, seems important. Shielding more young women from harmful impacts could reduce the gender gap even further.

Why then are these females still not as successful in the continuing competition as their male counterparts? The results of this study suggest that other approaches need to be tested to examine this question. We suggest looking more closely at new approaches and concepts that do not focus on stereotypes and social identity as the reasons for deciding against a career in science and, instead, focus on examining a combination of the internal and external factors behind this decision (see, e.g., Luttenberger et al., 2019b).

Overall, the results of this study provide a ray of hope for physics: If the females who are most likely to continue in science are immune to or not as affected by stereotypes as the average female student, stereotypes might not be such a big problem for the domain anymore. Although continuing to fight stereotypes might encourage more females to proceed to this level of pursuing physics, how to support those who have already reached this stage should also receive more attention. Nevertheless, this study shows that promising starting points for supporting interested females in science could be interventions that promote resilience and support the development of abilities and useful characteristics.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

AL wrote the first draft and collected the data. AL and OK contributed to the data analysis. All authors contributed to the manuscript, revised the manuscript critically, and approved it for submission.

Funding

The study was part of the project "Identiphy – Identity development in physics!," which was funded by the Bundesministerium für Bildung und Forschung (Grant number: 01 FP1717).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Alter, A. L., Aronson, J., Darley, J. M., Rodriguez, C., and Ruble, D. N. (2010). Rising to the threat: reducing stereotype threat by reframing the threat as a challenge. *J. Exp. Soc. Psychol.* 46, 166–171. doi: 10.1016/j.jesp.2009.09.014

Anger, C., Koppel, O., Plünnecke, A., Röben, E., and Schüler, R. M. (2019). *MINT - Grundlage für Forschung und Digitalisierung. Gutachten für BDA, BDI, MINT Zukunft schaffen und Gesamtmetall [STEM – Basis for research and digitalization].*

Archer, L., Moote, J., and MacLeod, E. (2020). Learning that physics is 'not for me': pedagogic work and the cultivation of habitus among advanced level physics students. *J. Learn. Sci.* 29, 347–384. doi: 10.1080/10508406.2019.1707679

Aronson, J., Fried, C. B., and Good, C. (2002). Reducing the effects of stereotype threat on African American college students by shaping theories of intelligence. *J. Exp. Soc. Psychol.* 38, 113–125. doi: 10.1006/jesp.2001.1491

Aronson, J., and Inzlicht, M. (2004). The ups and downs of attributional ambiguity: stereotype vulnerability and the academic self-knowledge of African American college students. *Psychol. Sci.* 15, 829–836. doi: 10.1111/j.0956-7976.2004.00763.x

Bailey, K. A., Horacek, D., Worthington, S., Nanthakumar, A., Preston, S., and Ilie, C. C. (2019). STEM/non-STEM divide structures undergraduate beliefs about gender and talent in academia. *Front. Sociol.* 4:26. doi: 10.3389/fsoc.2019.00026

Banchefsky, S., Lewis, K. L., and Ito, T. A. (2019). The role of social and ability belonging in men's and women's pSTEM persistence. *Front. Psychol.* 10:2386. doi: 10.3389/fpsyg.2019.02386

Bayly, B. L., and Bumpus, M. F. (2019). An exploration of engagement and effectiveness of an online values affirmation. *Educ. Res. Eval.* 25, 248–269. doi: 10.1080/13803611.2020.1717542

Bedyńska, S., Krejtz, I., and Sedek, G. (2018). Chronic stereotype threat is associated with mathematical achievement on representative sample of secondary schoolgirls: the role of gender identification, working memory, and intellectual helplessness. *Front. Psychol.* 9:428. doi: 10.3389/fpsyg.2018.00428

Ben-Zeev, T., Fein, S., and Inzlicht, M. (2005). Arousal and stereotype threat. *J. Exp. Soc. Psychol.* 41, 174–181. doi: 10.1016/j.jesp.2003.11.007

Blackwell, L. S., Trzesniewski, K. H., and Dweck, C. S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: a longitudinal study and an intervention. *Child Dev.* 78, 246–263. doi: 10.1111/j.1467-8624.2007.00995.x

Brady, S. T., Cohen, G. L., Jarvis, S. N., and Walton, G. M. (2020). A brief social-belonging intervention in college improves adult outcomes for black Americans. *Sci. Adv.* 6:eaay3689. doi: 10.1126/sciadv.aay3689

Burnette, J. L., O'Boyle, E. H., VanEpps, E. M., Pollack, J. M., and Finkel, E. J. (2013). Mind-sets matter: a meta-analytic review of implicit theories and self-regulation. *Psychol. Bull.* 139, 655–701. doi: 10.1037/a0029531

Cheryan, S., and Plaut, V. C. (2010). Explaining underrepresentation: a theory of precluded interest. *Sex Roles* 63, 475–488. doi: 10.1007/s11199-010-9835-x

Cheryan, S., Siy, J. O., Vichayapai, M., Drury, B. J., and Kim, S. (2011). Do female and male role models who embody STEM stereotyped hinder women's anticipated success in STEM? *Soc. Psychol. Personal. Sci.* 2, 656–664. doi: 10.1177/1948550611405218

Cohen, G. L., Garcia, J., Apfel, N., and Master, A. (2006). Reducing the racial achievement gap: a social-psychological intervention. *Science* 313, 1307–1310. doi: 10.1126/science.1128317

Cohen, G. L., Garcia, J., Purdie-Vaughns, V., Apfel, N., and Brzustoski, P. (2009). Recursive processes in self-affirmation: intervening to close the minority achievement gap. *Science* 324, 400–403. doi: 10.1126/science.1170769

de Jong, E. M., Jellesma, F. C., Koomen, H. M. Y., and de Jong, P. F. (2016). A values- affirmation intervention does not benefit negatively stereotyped immigrant students in the Netherlands. *Front. Psychol.* 7:691. doi: 10.3389/fpsyg.2016.00691

Deiglmayr, A., Stern, E., and Schubert, R. (2019). Beliefs in "brilliance" and belonging uncertainty in male and female STEM students. *Front. Psychol.* 10:1114. doi: 10.3389/fpsyg.2019.01114

Dietrich, J., and Lazarides, R. (2019). Gendered development of motivational belief patterns in mathematics across a school year and career plans in math-related fields. *Front. Psychol.* 10:1472. doi: 10.3389/fpsyg.2019.01472

Düchs, G., and Mecke, K. (2019). Vielfalt statt Einfalt. Statistiken zum Physikstudium an den Universitäten in Deutschland 2019 [Statistics to physics courses at German Universities in 2019]. *Phys. J.* 18, 26–31.

Dweck, C.S. (2000). *Self-Theories: Their Role in Motivation, Personality and Development.* Taylor & Francis Philadelphia, PA.

Ertl, B., and Hartmann, F. G. (2019). The interest profiles and interest congruence of male and female students in STEM and non-STEM fields. *Front. Psychol.* 10:897. doi: 10.3389/fpsyg.2019.00897

Estrada, M., Woodcock, A., Hernandez, P. R., and Schultz, P. W. (2011). Toward a model of social influence that explains minority student integration into the scientific community. *J. Educ. Psychol.* 103, 206–222. doi: 10.1037/a0020743

Faul, F., Erdfelder, E., Buchner, A., and Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. *Behav. Res. Methods* 41, 1149–1160. doi: 10.3758/BRM.41.4.1149

Faul, F., Erdfelder, E., Lang, A.-G., and Buchner, A. (2007). G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods* 39, 175–191. doi: 10.3758/BF03193146

Fennema, E., and Sherman, J. A. (1976). Fennema-Sherman Mathematics Attitude Scales: instruments designed to measure attitudes toward the learning of mathematics by females and males. *J. Res. Math. Educ.* 7, 324–326. doi: 10.2307/748467

Flore, P. C., and Wicherts, J. M. (2015). Does stereotype threat influence performance of girls in stereotyped domains? A meta-analysis. *J. Sch. Psychol.* 53, 25–44. doi: 10.1016/j.jsp.2014.10.002

Freeman, T. M., Anderman, L. H., and Jensen, J. M. (2007). Sense of belonging in college freshmen at the classroom and campus levels. *J. Exp. Educ.* 75, 203–220. doi: 10.3200/JEXE.75.3.203-220

Froehlich, L., Martiny, S. E., Deaux, K., Goetz, T., and Mok, S. Y. (2016). Being smart or getting smarter: implicit theory of intelligence moderates stereotype threat and stereotype lift effects. *Br. J. Educat. Psychol.* 55, 564–587. doi: 10.1111/bjso.12144

Ghazy, N., Ratner, E., and Rosenberg-Lee, M. (2019). Differential contributions of empathy to math achievement in women and men. *Front. Psychol.* 10:1941. doi: 10.3389/fpsyg.2019.01941

Gillen-O'Neel, C., and Fuligni, A. (2013). A longitudinal study of school belonging and academic motivation across high school. *Child Dev.* 84, 678–692. doi: 10.1111/j.1467-8624.2012.01862.x

Gonsalves, A. J., Cavalcante, A. S., Sprowls, E. D., and Iacono, H. (2021). "Anybody can do science if they're brave enough": understanding the role of science capital in science majors' identity trajectories into and through postsecondary science. *J. Res. Sci. Teach.* 58, 1117–1151. doi: 10.1002/tea.21695

Good, C., Rattan, A., and Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *J. Pers. Soc. Psychol.* 102, 700–717. doi: 10.1037/a0026659

Hall, W. M., Schmader, T., Aday, A., and Croft, E. (2018). Decoding the dynamics of social identity threat in the workplace: a within-person analysis of women's and men's interactions in STEM. *Soc. Psychol. Personal. Sci.* 10, 542–552. doi: 10.1177/1948550618772582

Hall, W. M., Schmader, T., and Croft, E. (2015). Engineering exchanges: daily social identity threat predicts burnout among female engineers. *Soc. Psychol. Personal. Sci.* 6, 528–534. doi: 10.1177/1948550615572637

Hannover, B., and Kessels, U. (2004). Self-to-prototype matching as a strategy for making academic choices. Why high school students do not like math and science. *Learn. Instr.* 14, 51–67. doi: 10.1016/j.learninstruc.2003.10.002

Hartley, B. L., and Sutton, R. M. (2013). A stereotype threat account of boys' academic underachievement. *Child Dev.* 84, 1716–1733. doi: 10.1111/cdev.12079

Hoferichter, F., and Raufelder, D. (2019). Mothers and fathers — who matters for STEM performance? Gender-specific associations between stem performance, parental pressure, and support during adolescence. *Front. Education* 4:14. doi: 10.3389/feduc.2019.00014

Höffler, T., Bonin, V., and Parchmann, I. (2017). Science vs. sports: motivation and self- concepts of participants in different school competitions. *Int. J. Sci. Math. Educ.* 15, 817–836. doi: 10.1007/s10763-016-9717-y

Höffler, T., Köhler, C., and Parchmann, I. (2019). Scientists of the future: an analysis of talented students' interests. *Int. J. STEM Educat.* 6, 1–8. doi: 10.1186/s40594-019-0184-1

Huguet, P., and Régner, I. (2009). Counter-stereotypic beliefs in math do not protect school girls from stereotype threat. *J. Exp. Soc. Psychol.* 45, 1024–1027. doi: 10.1016/j.jesp.2009.04.029

IBM Corp. (2015). *IBM SPSS Statistics for Windows, Version 23.0*. Armonk, NY: IBM Corp.

Jamieson, J. P., and Harkins, S. G. (2011). The intervening task method: implications for measuring mediation. *Personal. Soc. Psychol. Bull.* 37, 652–661. doi: 10.1177/0146167211399776

Johansson, A. (2020). Negotiation intelligence, nerdiness, and status in physics master's studies. *Res. Sci. Educ.* 50, 2419–2440. doi: 10.1007/s11165-018-9786-8

Kahn, S., and Ginther, D. K. (2015). Are recent cohorts of women with engineering bachelors less likely to stay in engineering? *Front. Psychol.* 6:1144. doi: 10.3389/fpsyg.2015.01144

Kalokerinos, E. K., Kjelsaas, K., Bennetts, S., and von Hippel, C. (2017). Men in pink collars: stereotype threat and disengagement among male teachers and child protection workers. *Eur. J. Soc. Psychol.* 47, 553–565. doi: 10.1002/ejsp.2246

Kessels, U., Rau, M., and Hannover, B. (2006). What goes well with physics? Measuring and altering the image of science. *Br. J. Educat. Psychol.* 76, 761–780. doi: 10.1348/000709905X59961

Ladewig, A., Keller, M., and Klusmann, U. (2020). Sense of Belonging as an important factor in the pursuit of physics: Does it also matter for female participants of the German Physics Olympiad? *Front. Psychol.* 11:548781. doi: 10.3389/fpsyg.2020.548781

Ladewig, A., Köller, O., and Neumann, K. (2022). Persisting in physics and the physics olympiad — impact of gender identification and sense of belonging on expectancy-value outcomes *Europ. J. Psychol. Educ.* doi: 10.1007/s10212-022-00600-5

Lin-Siegler, X., Ahn, J. N., Chen, J., Fang, F. -F. A., and Luna-Lucero, M. (2016). Even Einstein struggled: effects of learning about great scientists' struggles on high school students' motivation to learn science. *J. Educ. Psychol.* 108, 314–328. doi: 10.1037/edu0000092

Luhtanen, R., and Crocker, J. (1992). A collective self-esteem scale: self-evaluation of one's social identity. *Personal. Soc. Psychol. Bull.* 18, 302–318. doi: 10.1177/0146167292183006

Luttenberger, S., Paechter, M., and Ertl, B. (2019a). Self-concept and support experienced in school as key variables for the motivation of women enrolled in STEM subjects with a low and moderate proportion of females. *Front. Psychol.* 10:1242. doi: 10.3389/fpsyg.2019.01242

Luttenberger, S., Steinlechner, P., Ertl, B., and Paechter, M. (2019b). It takes more than one swallow to make a summer: measures to foster girls' and women's pathways into STEM. *Front. Psychol.* 10:1844. doi: 10.3389/fpsyg.2019.01844

Makarova, E., Aeschlimann, B., and Herzog, W. (2019). The gender gap in stem fields: the impact of the gender stereotype of math and science on secondary students' career aspirations. Frontiers. *Education* 4:60. doi: 10.3389/feduc.2019.00060

Marchand, G. C., and Taasobshirazi, G. (2013). Stereotype threat and women's performance in physics. *Int. J. Sci. Educ.* 35, 3050–3061. doi: 10.1080/09500693.2012.683461

Marx, D. M., Stapel, D. A., and Muller, D. (2005). We can do it: the interplay of construal orientation and social comparisons under threat. *J. Pers. Soc. Psychol.* 88, 432–446. doi: 10.1037/0022-3514.88.3.432

Miller, D. I., Eagly, A. H., and Linn, M. C. (2015). Women's representation in science predicts national gender-science stereotypes: evidence from 66 nations. *J. Educ. Psychol.* 107, 631–644. doi: 10.1037/edu0000005

Miller, D. I., and Wai, J. (2015). The bachelor's to Ph.D. STEM pipeline no longer leaks more women than men: a 30-year analysis. *Front. Psychol.* 6:37. doi: 10.3389/fpsyg.2015.00037

Miyake, A., Kost-Smith, L. E., Finkelstein, N. D., Pollock, S. J., Cohen, G. L., and Ito, T. A. (2010). Reducing the gender achievement gap in college science: a classroom study of values affirmation. *Science* 330, 1234–1237. doi: 10.1126/science.1195996

Murphy, M. C., Steele, C. M., and Gross, J. J. (2007). Signaling threat: how situational cues affect women in math science, and engineering settings. *Psychol. Sci.* 18, 879–885. doi: 10.1111/j.1467-9280.2007.01995.x

Pennington, C. R., Heim, D., Levy, A. R., and Larkin, D. T. (2016). Twenty years of stereotype threat research: a review of psychological mediators. *PLoS One* 11:e0146487. doi: 10.1371/journal.pone.0146487

Petersen, S., and Wulff, P. (2017). The German physics Olympiad – identifying and inspiring talents. *Eur. J. Phys.* 38, 1–16. doi: 10.1088/1361-6404/aa538f

Pittman, L. D., and Richmond, A. (2007). Academic and psychological functioning in late adolescence: the importance of school belonging. *J. Exp. Educ.* 75, 270–290. doi: 10.3200/JEXE.75.4.270-292

Rahn, G., Martiny, S. E., and Nikitin, J. (2020). Feeling out of place: internalized age stereotypes are associated with older employees' sense of belonging and social motivation. *Work Aging Retire.* 7, 61–77. doi: 10.1093/workar/waaa005

Rattan, A., Savani, K., Komarraju, M., Morrison, M. M., Boggs, C., and Ambady, N. (2018). Meta-lay theories of scientific potential drive underrepresented students' sense of belonging to science, technology, engineering, and mathematics (STEM). *J. Pers. Soc. Psychol.* 115, 54–75. doi: 10.1037/pspi0000130

Sadler, P., Sonnert, G., Hazari, Z., and Tai, R. (2012). Stability and volatility of STEM career interest in high school: a gender study. *Sci. Educ.* 96, 411–427. doi: 10.1002/sce.21007

Sanchis-Segura, C., Aguirre, N., Cruz-Gómez, Á. J., Solozano, N., and Forn, C. (2018). Do gender-related stereotypes affect spatial performance? Exploring when, how and to whom using a chronometric two-choice mental rotation task. *Front. Psychol.* 9:1261. doi: 10.3389/fpsyg.2018.01261

Saß, S., and Kampa, N. (2019). Self-concept profiles in lower secondary level – an explanation for gender differences in science course selection? *Front. Psychol.* 10:836. doi: 10.3389/fpsyg.2019.00836

Schmader, T. (2002). Gender identification moderates stereotype threat effects on women's math performance. *J. Exp. Soc. Psychol.* 38, 194–201. doi: 10.1006/jesp.2001.1500

Schmader, T., Hall, W., and Croft, A. (2015). "Stereotype threat in intergroup relations" in *APA Handbooks in Psychology®. APA Handbook of Personality and*

Social Psychology, vol. 2. Group Processes. eds. M. Mikulincer, P. R. Shaver, J. F. Dovidio and J. A. Simpson (American Psychological Association), 447–471.

Schmader, T., and Johns, M. (2003). Converging evidence that stereotype threat reduces working memory capacity. *J. Pers. Soc. Psychol.* 85, 440–452. doi: 10.1037/0022-3514.85.3.440

Schmader, T., Johns, M., and Barquissau, M. (2004). The costs of accepting gender differences: the role of stereotype endorsement in women's experience in the math domain. *Sex Roles* 50, 835–850. doi: 10.1023/B:SERS.0000029101.74557.a0

Schorr, A. (2019). Pipped at the post: knowledge gaps and expected low parental it competence ratings affect young women's awakening interest in professional careers in information science. *Front. Psychol.* 10:968. doi: 10.3389/fpsyg.2019.00968

Setterlund, M. B., and Niedenthal, P. M. (1993). "Who am I? Why am I here?" Self-esteem, self-clarity, and prototype matching. *J. Pers. Soc. Psychol.* 65, 769–780. doi: 10.1037/0022-3514.65.4.769

Shih, M., Pittinsky, T. L., and Ambady, N. (1999). Stereotype susceptibility: identity salience and shifts in quantitative performance. *Psychol. Sci.* 10, 80–83. doi: 10.1111/1467-9280.00111

Smyth, F. L., and Nosek, B. A. (2015). On the gender-science stereotypes held by scientists: explicit accord with gender-ratios, implicit accord with scientific identity. *Front. Psychol.* 6:415. doi: 10.3389/fpsyg.2015.00415

Sobieraj, S., and Krämer, N. C. (2019). The impacts of gender and subject on experience of competence and autonomy in STEM. *Front. Psychol.* 10:1432. doi: 10.3389/fpsyg.2019.01432

Song, J., Kim, S., and Bong, M. (2019). The more interest, the less effort cost perception and effort avoidance. *Front. Psychol.* 10:2146. doi: 10.3389/fpsyg.2019.02146

Spencer, S. J., Steele, C. M., and Quinn, D. M. (1999). Stereotype threat and women's math performance. *J. Exp. Soc. Psychol.* 35, 4–28. doi: 10.1006/jesp.1998.1373

Steegh, A. M., Höffler, T. N., Höft, L., and Parchmann, I. (2020). First steps toward gender equity in the chemistry Olympiad: understanding the role of implicit gender-science stereotypes. *J. Res. Sci. Teach.* 58, 40–68. doi: 10.1002/tea.21645

Steegh, A. M., Höffler, T. N., Höft, L., and Parchmann, I. (2021). Exploring science competition participants' expectancy-value perceptions and identification: a latent profile analysis. *Learn. Instr.* 74:101455. doi: 10.1016/j.learninstruc.2021.101455

Steegh, A. M., Höffler, T. N., Keller, M. M., and Parchmann, I. (2019). Gender differences in mathematics and science competitions: a systematic review. *J. Res. Sci. Teach.* 56, 1431–1460. doi: 10.1002/tea.21580

Steele, C. M., and Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *J. Pers. Soc. Psychol.* 69, 797–811. doi: 10.1037//0022-3514.69.5.797

Steele, C. M., Spencer, S. J., and Aronson, J. (2002). Contending with group image: the psychology of stereotype and social identity threat. *Adv. Exp. Soc. Psychol.* 34, 379–440. doi: 10.1016/s0065-2601(02)80009-0

Su, R., and Rounds, J. (2015). All STEM fields are not created equal: people and things interests explain gender disparities across STEM fields. *Front. Psychol.* 6:189. doi: 10.3389/fpsyg.2015.00189

van Veelen, R., Derks, B., and Endedijk, M. D. (2019). Double trouble: how being outnumbered and negatively stereotyped threatens career outcomes of women in STEM. *Front. Psychol.* 10:150. doi: 10.3389/fpsyg.2019.00150

Vinni-Laakso, J., Guo, J., Juuti, K., Loukomies, A., Lavonen, J., and Salmela-Aro, K. (2019). The relations of science task values, self-concept of ability, and stem aspirations among Finnish students from first to second grade. *Front. Psychol.* 10:1449. doi: 10.3389/fpsyg.2019.01449

Vohs, K. D., Park, J. K., and Schmeichel, B. J. (2013). Self-affirmation can enable goal disengagement. *J. Pers. Soc. Psychol.* 104, 14–27. doi: 10.1037/a0030478

Walton, G. M., and Cohen, G. L. (2007). A question of belonging: race, social fit, and achievement. *J. Personal. Soc. Psychol. Res.* 92, 82–96. doi: 10.1037/0022-3514.92.1.82

Watt, H. M. G., Bucich, M., and Dacosta, L. (2019). Adolescents' motivational profiles in mathematics and science: associations with achievement striving, career aspirations and psychological wellbeing. *Front. Psychol.* 10:990. doi: 10.3389/fpsyg.2019.00990

Wheeler, S. R., and Blanchard, M. R. (2019). Contextual choices in online physics problems: promising insights into closing the gender gap. *Front. Psychol.* 10:594. doi: 10.3389/fpsyg.2019.00594

Wille, E., Gaspard, H., Trautwein, U., Oschatz, K., Scheiter, K., and Nagengast, B. (2018). Gender stereotypes in a children's television program: effects on girls' and boys' stereotype endorsement, math performance, motivational dispositions, and attitudes. *Front. Psychol.* 9:2435. doi: 10.3389/fpsyg.2018.02435

Yeager, D. S., Walton, G. M., Brady, S. T., Akcinar, E. N., Paunesku, D., Keane, L., et al. (2016). Teaching a lay theory before college narrows achievement gaps at scale. *Proc. Natl. Acad. Sci. U. S. A.* 113, E3341–E3348. doi: 10.1073/pnas.1524360113

Yeager, D. S., Walton, G. M., and Cohen, G. L. (2013). Addressing achievement gaps with psychological interventions. *Phi Delta Kappan* 94, 62–65. doi: 10.1177%2F003172171309400514