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Gender does not make the difference: interest in STEM by gender is fully mediated by technical socialization and degree program

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Abstract
In Germany, there is a shortage of skilled workers in the fields of science, technology, engineering, and mathematics (STEM) and especially in technology with declining interest in technology and with supposedly fewer teachers in technology education in the next 20 years. The present study examined whether students' interest in STEM is dependent on their career choices (i.e., their degree program), their technical socialization, their personality, and gender. A survey in Germany, Baden-Wuerttemberg ($N = 350$) examined gender-specific differences in teacher training students with and without technology and engineering students via structural equation modelling with the mediators personality, technical socialization, and degree program. Results show that interest in STEM by gender is fully mediated by technical socialization and degree program. Solutions for the reduction of the staff shortage and gender gap in the technical domain are discussed and it is suggested that an integration of technology lessons in the school curriculum and a reduction of gender normatives may help.

Keywords Gender and technology · Choice of vocation · General technology education · Teacher training · Interest in STEM

Introduction

The use of technical artefacts is of increasing importance for everyday life, e.g., when checking on the weather app or the cruise control app in the car (Baaser, 2021). However, students' interest in technology is continuously declining (acatech, 2011; acatech & Körber Stiftung, 2021; Tenberg, 2016). Therefore, proficient teachers of technology education are needed to act as experienced role models in order to inspire and spark students' interest for technical content and act as multiplicators of future STEM careers.

Females are highly underrepresented in STEM fields and career choices are strongly gendered (Salchegger et al., 2019; Statistisches Landesamt Baden-Württemberg, 2019).

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Technical socialization (e.g., family background and education) determines career choices, e.g., in the domain of education, female teacher trainer's choice for or against a STEM subject is determined by the student's contact with technical aspects in their socialization. In the past, males were socialized closer to technical aspects than females and the teachers' implicit gender stereotypes lead to tracking recommendations that perpetuate the existing gender gap (Nürnberger et al., 2016).

Gender

Gender is defined as gender identity, e.g., cisgender, transgender, gender fluid, agender; gender is also defined as gender expression, i.e., gender-conforming or non-conforming appearance, behavior or activities (Leaper & Brown, 2018), e.g., dressing up or playing soccer. Gender refers to social sex and is not to be understood in biological terms, but rather to ascribed social and cultural expectations (Rendtorff, 2017; Wirtz, 2013), including activities linked to technology education. Parents, siblings, peers and teachers encourage gender-normative activities and discourage non-normative activities by, e.g., rejection or bullying (Leaper & Brown, 2018). Consequently, sexism is present as implicit prejudices, subtle reinforcements of stereotypical behaviors or self-socialization to peer group norms (Leaper & Brown, 2018).

Technology education

Technology education is a curriculum subject in which students learn about the knowledge and processes that are needed to manipulate materials and tools, thereby extending the human's ability to shape and change the physical world (ITEA, 2006). In primary and secondary school, technology education (U.S.) or design and technology (U.K.) are curriculum subjects and are part of the STEM education. However, they are marginalized, i.e., perceived to be of less value than their STEM counterparts science and mathematics (Bell et al., 2017). While science and mathematics stand for academic knowledge, the fields of design, technology, and engineering cover vocational skills (Bell et al., 2017).

Currently, due to technological progress, the gap between a wide usage of digital tools in the general population and the lack of knowledge about their technical components largens (ITEA, 2006; U.S. Department of Education, 2017). This societal dependency on technology requires more engagement in technology education (Baaser, 2021). The goal of technology education in a world shaped by technology must therefore be to develop responsible citizens (Theuerkauf, 2013).

In the German-speaking countries (Austria, Germany, and Switzerland), there are different curriculum subjects covering technology, e.g., science and technology [Naturwissenschaft und Technik], handicrafts [Werken], textile and technical design [Textiles und Technisches Gestalten], and technology [Technik]. Technology education must always be understood as compulsory education in primary and secondary education (Ropohl, 2009) and must not be oriented towards boys only, as shown, for example, by the way in which students make choices regarding high school electives in Baden-Württemberg (Statistisches Landesamt Baden-Württemberg, 2019) and in Austria (Sutterlüti, 2013). Therefore, compulsory technology education with its link to vocational training (Landesinstitut für Schulentwicklung, 2016) is an important task in order to pick up as many children and young people as possible and to educate them as responsible citizens of the future. The curriculum subject technology education is distinct from media education, often referred to as technological knowledge (Schmidt et al., 2009) and vocational technology, e.g., engineering.

The present study

The aim of the present study was to examine the influence of gender, students' personality, their technical socialization, and study subject choice on their interest in STEM. It is assumed that a student's personality, technical socialization and the enrolled degree program act as mediators for the relation between gender and interest in STEM and therefore strengthen or weaken the correlation of gender and interest in STEM. The present study therefore conducted a quantitative survey among students in Baden-Wuerttemberg, Germany ($N = 350$) and compared four degree programs: teacher training with a major in technology, teacher training with a minor in technology, teacher training without the subject technology, and engineering. The mediation hypotheses were tested in a structural equation model (SEM).

Research question

There is a gender gap in technology education teachers with more male than female teachers. The present study examines the origins of this gender gap by analyzing whether students' interest in STEM is dependent on their career choices, their technical socialization, personality, and gender.

Theoretical background

The skill shortage in technology education and engineering

Shortage in engineering

A shortage of skilled workers in the technical context, e.g., in the form of unfilled apprenticeship positions (DIHK, 2019) and field-specific high dropout rates have already been drawing media attention to the issue for several years. More than 30% of vocational training contracts are abandoned before completion (e.g., 36% in metal construction; acatech & Körber Stiftung, 2021) and the number of vocational training contracts was decreasing by 12% in 2020 with only 3% as a result of the COVID-19 pandemic (acatech & Körber Stiftung, 2021). The number of STEM students in tertiary education is high (acatech & Körber Stiftung, 2021), however, 35% of bachelor students in engineering abandon their studies before completion (Heublein & Schmelzer, 2018).

Shortage in STEM teachers

There is a considerable lack of STEM teachers, e.g., at vocational colleges (Zinn, 2018). Although the German numbers of first-year teacher training students in STEM subjects is increasing since 2015, the increase is insufficient and the STEM fields are short on teachers, especially in the subject of technology education (acatech & Körber Stiftung, 2020, 2021). Correspondingly, the majority of pupils are not offered the possibility to choose technology as a standalone subject and the percentage of pupils choosing a STEM major in secondary education is decreasing since 2014 (acatech & Körber Stiftung, 2021). Technology education in Germany, also as a link to vocational training (Landesinstitut für Schulentwicklung, 2016) should play a more important role in order to better prepare students for STEM careers.

Interest in STEM

Hill et al. (2010) cite barriers within STEM careers: Aptitude for the career field and the perceived superiority of men in mathematics, perceived disinterest of girls/women and work-life balance (problems at the workplace). The interest of technology and design teachers in different content areas and, related to this, their self-assessed level of knowledge in these areas is strongly gendered (Goreth, 2021). Gender differences in, for example, attitudes or motivation toward technology are repeatedly demonstrated (Sansone, 2017; Virtanen et al., 2015) and as summed up in a recent review, girls share more negative views towards STEM and are more reluctant to participate in STEM fields than boys (Sultan et al., 2019). The gender gap in interest in STEM has also been monitored in teacher training students with males reporting higher interest in STEM than females (Marth & Bogner, 2019). These individual differences in interest in STEM are linked to personality, socialization and have consequences for career choices (Wang & Degol, 2013).

The gender gap in technology education and engineering

Gender today mostly refers to social sex and combines ascribed characteristics (e.g., personality traits) and expected behaviors (Schmader & Block, 2015). Thus, current definitions of gender are determined by socially shaped roles with male and female attributes and distinguish themselves from those of years past, which refer to sex in purely biological terms (Bührer & Schraudner, 2006).

Gender gap in engineering

The gender gap in engineering existed in the past (acatech & VDI, 2009; Sachs, 1987) and still prevails with males dominating in technology (BMBF, 2018) and only 11% of vocational training contracts taken by females (acatech & Körber Stiftung, 2021). Significant gender differences within physics competencies are visible in several countries (Salchegger et al., 2019). Especially when biology is not included, there is a clear gap in the proportion of female first-year students planning to pursue a degree in engineering, computer science or physics, both in the USA (Foley, 2009; Foley et al., 2019) and in Germany (Aeschlimann et al., 2015; Augustin-Dittmann & Gotzmann, 2015). When females choose to study STEM, their preference is mathematics or biology, while they are underrepresented in engineering (Gomez Soler et al., 2020). While the number of females is increasing in some domains of STEM, this is not the case in engineering with only 25% females in this sector of tertiary education (acatech & Körber Stiftung, 2021). Gender-specific career choices in the context of STEM are the focus of major research institutions predominantly due to an economically induced growing shortage of skilled workers (acatech & Körber Stiftung, 2021). However, previous model projects for the promotion of girls in STEM do not bring the overriding success (acatech, 2011). Moreover, if they do study engineering, females share different values than males: females engineering students emphasize altruistic values, e.g., contributing to a better society and environment, while male engineering students emphasize practical and technical aspects of the profession (Engström, 2018).

Gender gap in STEM teachers

About two out of three teacher training students are female (acatech & Körber Stiftung, 2020). However, less female teacher training students choose technology as a major or minor subject. Female teachers could act as a role model to foster girls' interest in STEM careers (Swafford & Anderson, 2020). Strikingly, in the field of technology teacher training, gender research is strongly underrepresented. As a consequence of these preconditions, girls do not have female role models and come to the conclusion that STEM is not for them because school science is perceived as hard, encounters with real STEM experiences and opportunities of practice play are scarce at school and at home (Aschbacher et al., 2010), or the differently designed nature of a conservative family planning can be stated against the choice for a STEM career (Sassler et al., 2017).

Hypothesis 1 Following these findings, we hypothesize that the degree program has an impact on the relation between gender and interest in STEM: Interest in STEM by gender is mediated by degree program (Fig. 1). We suppose that choosing a technical degree program is dependent on the student's gender and that technical degree programs reinforce interest in STEM.

Looking for answers: personality and socialization

Personality

The gender gap in STEM is explained by gendered occupational preferences rooted in personality. Within STEM education, girls and boys differ in their self-concept in practical technical work with girls acting more insecure than boys (acatech, 2011; Brämer, 2019), reporting lower self-efficacy (Aguillon et al., 2020), and boys being more self-confident and enthusiastic about crafts and tools (Virtanen et al., 2015). While gender differences in personality play a role, these results also depend on actual skill levels (Jann & Hupka-Brunner, 2020) and have a clear influence on the choice of a technical career or degree program. Boys are more likely than girls to attribute their successes to their abilities (internal stability), whereas girls attribute failures to their perceived lower abilities (Finsterwald et al., 2012; McClure et al., 2011; Solga & Pfahl, 2009). Male students act more

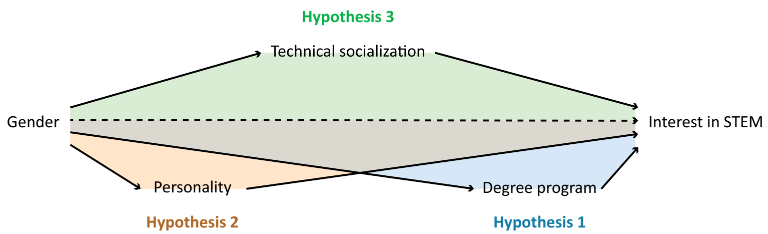

Fig. 1 Theoretical path diagram – facilitators of students' interest in STEM

dominantly in their practical learning activities in STEM courses (Aguillon et al., 2020). A central aspect of professional identity of the subject technology education is problem-solving. The selection of the respective strategies for solving a problem allows recourse to already known tools and methods. In this context, the concept of creativity is often included in addition to technical expertise (Haas et al., 2018). The enjoyment and engagement in problem or thinking tasks (Cacioppo & Petty, 1982) can be considered an essential basis. Besides GPA and math skills, conscientiousness is related to retention in engineering students (Hall et al., 2015).

Hypothesis 2 We therefore hypothesize that the relationship between gender and interest in STEM is mediated by personality: Interest in STEM by gender is mediated by personality (Fig. 1). In detail, we hypothesize that females with higher interest in STEM are more conscientious and have a higher need for cognition than females with lower interest in STEM.

Technical socialization

Students use a wide range of in-school and out-of-school information to make career choices (Schuhen & Schürkmann, 2015). Career choices are influenced by gender identity, a gender-normative environment of parents, siblings and friends acting as gatekeepers or facilitators (Brämer, 2019; van Tuijl & van der Molen, 2016).. Technology-related gender stereotypes already exist in kindergarten and become more entrenched with increasing age (Freeman, 2007; Hallström et al., 2015). Females prefer STEM majors only when they have an older sister with interest in STEM or male siblings in general (Gabay-Egozi et al., 2022). Gender-normative ideas in their peer circle prevents girls from pursuing STEM careers (van der Vleuten et al., 2018). Boys are more likely than girls to be encouraged by parents, educators, and teachers to engage with technology (Finsterwald et al., 2012; Hallström et al., 2015; Mawson, 2007). Gender-normative ideas are present in primary school, e.g., when participating in technical education (Sultan et al., 2020) and in secondary school with a normative male preference for STEM (Beckmann, 2021). Female students within engineering have to fight against these stereotypes in order to make this decision (Gorlov, 2009). Moreover, it can be shown that women with STEM degrees prefer spatial toys in childhood more than women in non-STEM degrees (Moè et al., 2018). Therefore, interest in STEM as well as STEM-related self-efficacy and resulting career choices – which reinforce the interest in STEM – are deeply rooted in the childhood (van Tuijl & van der Molen, 2016). Thus, individual differences in interest in STEM may be explained by a child's socialization with different exposure to technology and different social expectations for girls and boys (Sultan et al., 2019).

The decision for a STEM career becomes even more challenging because females tend to have a greater salience of gender identity, that is, they adhere more closely to their gender role than males (Aguillon et al., 2020). The gender segregation in extracurricular activities and the high school STEM curriculum have a significant impact on plans to pursue STEM (Legewie & DiPrete, 2014). Boys, on the other hand, experience a greater connection to engaging with technology than girls (Finsterwald et al., 2012; Hallström et al., 2015; Mawson, 2007), and these gender differences in interest in, e.g., computer science, engineering, and physics become evident before college (Cheryan et al., 2017) and lead to active avoidance of activities that are in conflict with gender identity (Schmader & Block, 2015), e.g. hands-on engagement in technology for females. Therefore, the early gender specific technical socializations in the close circle of family and friends plays a role.

Hypothesis 3 Thus, we assume that the technical socialization plays a mediating role in the relation between gender and interest in STEM: Interest in STEM by gender is mediated by technical socialization (Fig. 1).

The three hypotheses are illustrated in Fig. 1. Since this theoretical path diagram is a simplification, aside from these relations, other relationships are possible and plausible: The relationship of gender and degree program may be mediated by personality traits, e.g., females need to be more conscientious than males when choosing a degree program with a technological content (teacher training with technology major, technology minor, or engineering). Also, a mediation of the relationship of technical socialization and interest in STEM by the degree program could be possible. The present study not only examines the three hypotheses, but all possible relationships in the model (Fig. 1) are tested via structural equation modelling.

Materials and methods

The sample

The sample consists of teacher training students from university colleges of teacher education in Karlsruhe, Heidelberg, Ludwigsburg, and Schwäbisch Gmünd as well as mechanical engineering students from the Karlsruhe Institute of Technology (a technical university) and the University of Stuttgart, all located in the South-West of Germany in the federal state of Baden-Württemberg. The total sample size was $N=350$ students (34% females, 65% males, 1% non-binary). The participants were on average in the 4th semester ($M=4.12$, $SD=2.41$) and studied in the following degree programs:

- Teacher training, technology major: Semester, $M=4.05$, $SD=2.91$, $n=63$; 49 males, 12 females,
- Teacher training, technology minor: Semester, $M=4.56$, $SD=2.62$, $n=155$; 107 males, 48 females,
- Teacher training without technology: Semester, $M=3.45$, $SD=1.70$, $n=69$; 21 males, 48 females,
- Mechanical engineering: Semester, $M=3.87$, $SD=1.25$, $n=54$; 48 males, 6 females.

All students in these degree programs in a radius of 100 km around the University of Education Ludwigsburg were eligible for participation. Thus, about 25% of the population “teacher training students with technology major/minor” participated. The other two groups served as control groups.

The questionnaire

The following scales were used to operationalize the constructs mentioned in the hypotheses: BIG-Five personality, need for cognition, technical socialization, and interest in STEM.

BIG-Five personality (BFI-S)

The psychological concept of the BIG Five approach captures personality traits. Five central personality dimensions (neuroticism, extraversion, openness to experience, agreeableness, conscientiousness) subdivide the construct. The individual expression can be very different (Gerlitz & Schupp, 2005). The instrument, which has been replicated in many languages, was modified by the authors on the basis of various criteria (1. framework conditions as well as restrictions in the questionnaire; 2. content balance of the items of a scale; 3. internal consistency of the scales; 4. dimensionality of the item battery; 5. representation of the BFI-25) to 15 items with a test time of 2 min (Gerlitz & Schupp, 2005). The response format of the test scale used was adapted (Likert-scaled: 1 = "Strongly disagree" to 5 = "Strongly agree", Cronbach's α, conscientiousness = 0.45, extraversion = 0.73, agreeableness = 0.49, openness = 0.55, neuroticism = 0.68).

Need for cognition (NFC)

This scale measures enjoyment of and engagement in problem or thinking tasks and was developed by Cacioppo and Petty (1982), German version by Preckel (2014). The tendency for the individual positive perception of conscious analytic activities is delimited from cognitive abilities and shows a unidimensional structure. The test, which was adapted into German, contains 19 items on a 5-point Likert scale (1 = "do not agree at all" to 5 = "agree completely"; Cronbach's α = 0.85).

Technical socialization

To measure technical socialization, items from the MINT-Nachwuchsbarometer (acatech & VDI, 2009) were combined with newly developed items. From the broad question areas of the MINT-Nachwuchsbarometer, these technology-oriented items were included: Technical and scientific play and object references ("How often did you deal with these things? (1) remote-controlled models, (2) model railway, (3) unscrewing devices, (4) electrical circuits/soldering, (5) handicrafts, (6) self-made repairs, and (7) helping with repairs" (acatech & VDI, 2009). Further, parental encouragement of interest in technology was measured with two items "My interest in (8) science/(9) technology was encouraged by my family (acatech & VDI, 2009). Moreover, pre-professional technical activity was measured with 6 newly developed items: "During my school years … (10) …I often had technology-related sideline activities (e.g., mini-job in a workshop), (11) …I often visited technical museums with my parents/friends (e.g., Experimenta), (12) …I worked a lot on motor vehicles (e.g. on a moped), (13) …I mainly did repair work at home together with (one of) my parents, (14) …I mainly did self-made repairs at home alone, and (15) …I often attended extracurricular technology events (e.g. technology club)". Thus, the newly developed items were also focused on technical activity in adolescence. The resulting index of Section "technical socialization" consists of 15 items (1 "never" to 6 "very often", Cronbach's α = 0.90).

Interest in STEM

To measure interest in STEM, items from the MINT-Nachwuchsbarometer (acatech & VDI, 2009) were used. "How is your current interest in … Mathematics, Physics, Biology, Chemistry, Computer Science, Computer Technology, Electrical Engineering, Civil Engineering, Production Engineering, and Renewable Energy?" (10 items, 1 "very low" to 6 "very high", Cronbach's $\alpha = 0.75$).

Gender was measured with three response categories (male, female, non-binary). In addition, the several control variables were included in the questionnaire: age (in years), technology education in school ("Did you have technology as a school subject?" – 0 = no technology, 1 = technology as part of science, 2 = standalone technology), school leaving grades (baccalaureate, 1 = D grade to 4 = A grade, higher values indicating better grades), vocational training in technology ("Before you started your studies, did you complete a vocational training in technology?" – 0 = no/not completed 1 = yes, completed), degree program (1 = teacher training with technology major, 2 = teacher training with technology minor, 3 = teacher training without technology, 4 = engineering).

Moreover, the teacher training students answered questions on their study motivation (Pohlmann & Möller, 2010) and on their self-concept (Retelsdorf et al., 2014). However, preliminary analyses revealed no significant differences by degree program (teacher training students) and therefore these variables were not included in the analyses.

Data analysis strategy

For the visual display on the x-axis in Figs. 1, 2 and 3, the continuous variables of conscientiousness and technical socialization were categorized (33% low, 33% medium, 33% high). Regarding gender, the category "non-binary" was not included in the analyses because of the low sample size. After bivariate analyses, calculated in SPSS 26 (IBM Corp, 2019), a structural equation model (SEM) including all study variables was implemented in Mplus 7 (Muthén & Muthén, 1998–2012). The SEM examined direct and indirect effects (mediation analyses with bias-corrected bootstrapping) of gender, personality (BIG-5 and need for cognition), technical socialization and field of study on interest in STEM. The results were visualized using Adobe Illustrator (Adobe Systems, 2012).

Results

Most of the students were between 21 and 26 years old ($M = 24.5$, $SD = 4.4$, with a range from 19 to 54 years). A total of 81 students (23.1%) stated that they had completed vocational training in an industrial/technical field (e.g., mechatronics technician, carpenter, etc.) prior to their studies. The baccalaureate grade was $M = 2.48$ ($SD = 0.52$) on average.

Conscientiousness, agreeableness, and neuroticism were higher in females while technical socialization and interest in STEM were higher in males (Table 1). The gender difference was strong for technical socialization and medium for interest in STEM. When comparing the degree programmes, teacher training students without technology scored higher on neuroticism, lower on need for cognition, lower on technical socialization, and lower on interest in STEM than the other degree programs while engineering students scored lower on extraversion, agreeableness, and openness. The degree program effects were strong in technical socialization and interest in STEM (Table 1).

The differences in technical socialization by gender varied consistently with low, medium and high conscientiousness (Fig. 2) and an ANOVA revealed no interaction effect. Interest in STEM was associated with technical socialization: the higher the technical socialization, the higher the interest in STEM. This relation seems to be consistent when

Table 1 Mean differences by gender and degree program

	Gender	*M*	*SD*	*N*	*p*	η^2	Degree program	*M*	*SD*	*N*	*p*	η^2
Need for cognition	Male	3.56	0.49	228	0.056	0.011	Tech major	3.58	0.52	63	< 0.001	0.060
	Female	3.44	0.57	118			Tech minor	3.55	0.51	153		
							Without tech	3.31	0.51	69		
							Engineering	3.71	0.47	54		
Conscientiousness	Male	3.61	0.65	229	0.001	0.033	Tech major	3.78	0.58	63	0.187	0.015
	Female	3.84	0.66	118			Tech minor	3.71	0.68	154		
							Without tech	3.56	0.69	69		
							Engineering	3.66	0.60	54		
Extraversion	Male	3.80	0.77	229	0.850	< 0.001	Tech major	3.81	0.77	63	0.002	0.046
	Female	3.79	0.83	118			Tech minor	3.93	0.75	154		
							Without tech	3.71	0.88	69		
							Engineering	3.45	0.81	54		
Agreeableness	Male	4.01	0.70	229	0.043	0.012	Tech major	4.20	0.61	63	< 0.001	0.057
	Female	4.16	0.58	118			Tech minor	4.16	0.60	154		
							Without tech	3.98	0.71	69		
							Engineering	3.76	0.71	54		
Openness	Male	3.74	0.74	229	0.455	0.002	Tech major	3.67	0.66	63	0.017	0.031
	Female	3.79	0.74	118			Tech minor	3.88	0.73	154		
							Without tech	3.69	0.83	69		
							Engineering	3.60	0.70	54		
Neuroticism	Male	2.84	0.83	229	0.001	0.032	Tech major	2.89	0.84	63	0.011	0.033
	Female	3.16	0.90	118			Tech minor	2.83	0.83	154		
							Without tech	3.23	0.93	69		
							Engineering	3.06	0.89	54		
Technical socialization	Male	3.75	0.93	228	< 0.001	0.169	Tech major	3.90	0.76	63	< 0.001	0.351
	Female	2.84	1.04	117			Tech minor	3.55	0.82	154		
							Without tech	2.27	0.97	67		

Table 1 (continued)

	Gender	*M*	*SD*	*N*	*p*	η^2	Degree program	*M*	*SD*	*N*	*p*	η^2
							Engineering	4.11	0.93	54		
Interest in STEM	Male	3.64	0.75	228	< 0.001	0.113	Tech major	3.82	0.69	63	< 0.001	0.383
	Female	3.04	0.98	118			Tech minor	3.65	0.66	154		
							Without tech	2.38	0.85	69		
							Engineering	3.82	0.57	54		

BIG-5 personality, need for cognition: 1 = “strongly disagree” to 5 = “strongly agree”; technical socialization and interest in STEM: 1 = “strongly disagree” to 6 “strongly agree”

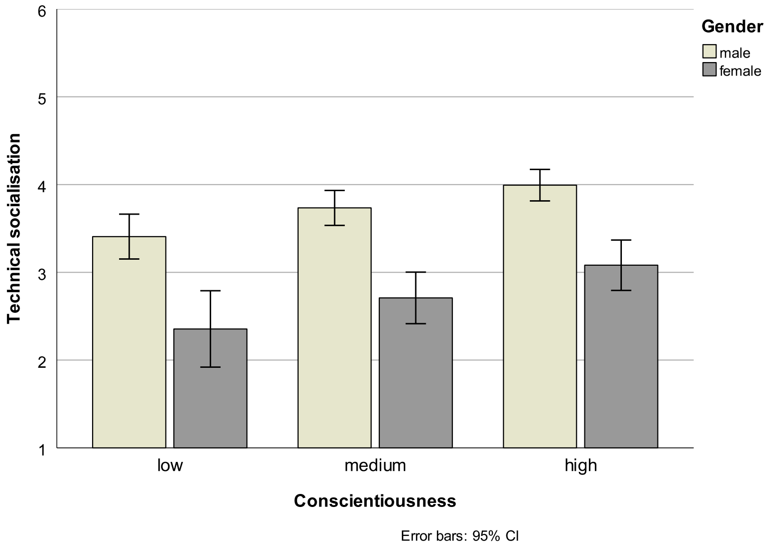

Fig. 2 Technical socialization by conscientiousness and gender *Note*: Technical socialization, 1 = "never" to 6 = "very often"

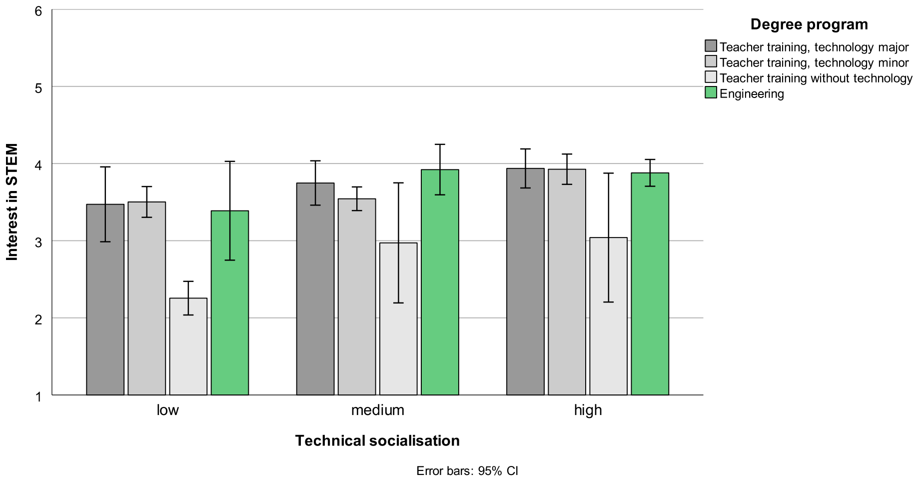

Fig. 3 Interest in STEM by technical socialization and degree program *Note*: Interest in STEM, 1 = "very low" to 6 = "very high"

the degree programs are inspected separately (Fig. 3) and an ANOVA also revealed no interaction effect. From visual inspection, the association of gender and interest in STEM seems to be mediated by technical socialization (Fig. 4). While in males, the association between technical socialization and interest in STEM was weak, this association was stronger in females. ANOVA analysis revealed an interaction effect ($p < 0.001$).

Technical socialization was highly correlated with interest in STEM (Table 2). There were weak correlations for the personality dimensions with technical socialization

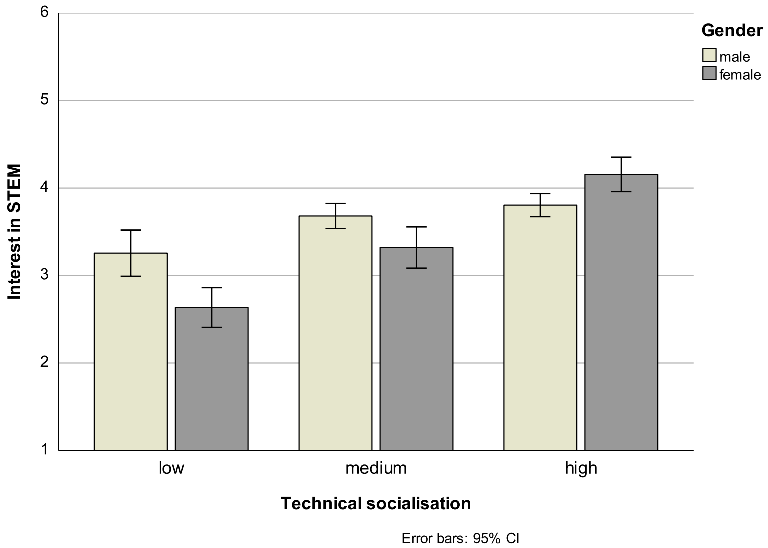

Fig. 4 Interest in STEM by technical socialization and gender *Note*: Interest in STEM, 1 = "very low" to 6 = "very high"

except for agreeableness. Interest in STEM was associated with need for cognition; the correlation coefficient was medium in size. There was no relation between the BIG-5 personality dimensions and interest in STEM (Table 2).

The SEM (Fig. 5) explained 48.7% of the variance in interest in STEM, 33.5% of the variance in the teacher training students without a major/minor in technology) and 27.4% of the variance in technical socialization. The strong bivariate association between technical socialization and interest in STEM ($r = 0.538$) was partially mediated by the degree programs (Fig. 5).

Summed up, the model revealed the following relations of partial and full mediation (mediation analyses with bias-corrected bootstrapping; CI = 2.5% upper and 2.5% lower confidence interval):

- The relationship of gender and interest in STEM was fully mediated by the degree program teacher training without technology (confirming hypothesis 1).
- Hypothesis 2 (interest in STEM by gender is mediated by personality) was not confirmed.
- The relationship of gender and interest in STEM was fully mediated by technical socialization (confirming hypothesis 3).
- Furthermore, the relationship of gender and technical socialization was partially mediated by conscientiousness.
- The relationship of technical socialization and interest in STEM was partially mediated by subject teacher training without technology.
- The relationship of conscientiousness and subject (engineering) was partially mediated by school leaving grades (Fig. 5).

Table 2 Correlations of study variables

		1 Gender	2 Age	3 Con-scient-iousness	4 Extra-version	5 Agree-ableness	6 Open-ness	7 Neuro-ticism	8 Need for Cognition	9 Tech. soci-alization	10 Tech. in school	11 Bacc. grades	12 Vocational training	13 Tech major	14 Tech minor	15 Without tech	16 Engineer
1	Gender (male = 0, female = 1)																
2	Age	−0.217***															
3	Conscien-tiousness	0.170**	0.033														
4	Extraversion	−0.006	0.117*	0.101													
5	Agreeable-ness	0.106*	−0.059	0.228***	0.084												
6	Openness	0.034	0.131*	0.078	0.209***	0.004											
7	Neuroticism	0.179**	−0.110*	−0.047	−0.203***	−0.058	−0.057										
8	Need for cognition	−0.103	0.083	0.284***	0.002	0.068	0.151**	−0.107*									
9	Technical socializa-tion	−0.406***	0.157**	0.176**	0.136*	0.015	0.167**	0.194***	0.292***								
10	Technology education in school	−0.170**	0.099	0.052	0.093	−0.078	0.058	0.002	0.032	0.294***							
11	School leav-ing grades	0.051	−0.026	0.246***	−0.029	0.012	−0.026	0.078	0.075	0.058	0.100						
12	Vocational training in technology	−0.247***	0.357***	0.058	0.061	−0.049	0.038	−0.100	0.071	0.240***	0.277***	0.133*					

Table 2 (continued)

	1 Gender	2 Age	3 Con-scient-iousness	4 Extra-version	5 Agree-ableness	6 Open-ness	7 Neuro-ticism	8 Need for Cognition	9 Tech. soci-alization	10 Tech. in school	11 Bacc. grades	12 Vocational training	13 Tech major	14 Tech minor	15 Without tech	16 Engineer
13 Teacher training, technology major	−0.138*	0.076	0.073	0.017	0.097	−0.059	−0.035	0.048	0.204***	0.150**	0.033	0.057				
14 Teacher training, technology minor	−0.052	0.162**	0.031	0.162**	0.125*	0.152**	−0.133*	0.024	0.087	−0.107*	−0.265***	−0.033				
15 Teacher training without technology	0.385***	−0.155**	−0.095	−0.051	−0.066	−0.046	0.155**	−0.217***	−0.556***	−0.181**	0.017	−0.193***				
16 Engineering	−0.207***	−0.133*	−0.015	−0.182**	−0.201***	−0.092	0.048	0.155**	0.269***	0.184**	0.308***	0.196***				
17 Interest in STEM	−0.324***	0.135*	0.078	0.045	0.048	0.036	−0.095	0.420***	0.538***	0.156**	0.075	0.120*	0.200***	0.206***	−0.614***	0.182**

Correlation coefficients, φ for the binary variables (lines 1, 12–16) and r for the continuous variables; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Lines 3–7, personality; 13–16, degree program

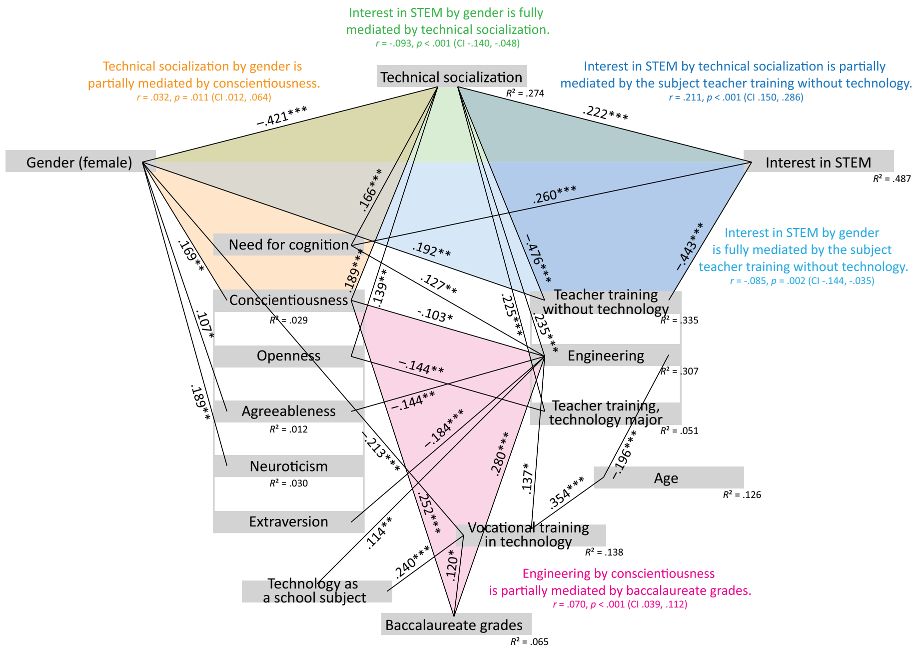

Fig. 5 Path diagram of interest in STEM *Note*: Structural equation model calculated in Mplus 7; $N = 343$; standardized regression coefficients of significant effects are shown, $*p < 0.05$, $**p < 0.01$, $***p < 0.001$; fit-indices: χ^2/df = 2.52, RMSEA = 0.067, CFI = 0.869, TLI = 0.810, SRMR = 0.065

Discussion

Hypotheses 1 and 3 were fully confirmed since the relationship between gender and interest in STEM was fully mediated by technical socialization and degree program, respectively. Hypothesis 2 was not confirmed, but the SEM found another triangle of mediation which was not considered by our model: The relation between gender and technical socialization was partly mediated by conscientiousness. However, interest in STEM was not associated with conscientiousness but the medium strength bivariate correlation between need for cognition and interest in STEM persisted in the SEM. Another very interesting finding of the SEM is that the relationship between conscientiousness and the choice of the degree program engineering, which was non-significant in the bivariate correlation, becomes a significantly negative one and is mediated by baccalaureate grades. That is, less conscientious students with better grades are more likely to choose engineering as a subject of study.

Discussion of hypothesis 1

The correlation between technical socialization and interest in STEM was partially mediated by the choice of degree program. This adds to previous work that showed that technology lessons in school are correlated with interest in MINT (acatech & VDI, 2009). Furthermore, there was a correlation between the attendance of a technology class at school and a subsequent technical vocational training. In German federal states, there is no compulsory technology education. Thus, implementing technology education as a school subject for all pupils would increase the number of adolescents starting an apprenticeship. Contrary to previous research which found a positive relation of conscientiousness and persistence in studying engineering (Hall et al., 2015), in the present study, conscientiousness was negatively related to studying engineering and this negative relation was partially mediated by the baccalaureate grades, suggesting that students with better grades and lower conscientiousness are more likely to study engineering.

Discussion of hypothesis 2

Regarding gender and personality, especially the BIG-5-dimension openness is interesting, because it conveys ideas that are in opposition to the prevailing gender norms. The results show that openness was related to higher technical socialization; teacher training students scored lower on openness. Openness was not related to gender, which is in accordance with the literature (Weisberg et al., 2011). In line with Weisberg et al. (2011), females scored higher on agreeableness and neuroticism but also scored higher on conscientiousness.

Discussion of hypothesis 3

In line with previous research, gender was related to technical socialization (acatech & Körber Stiftung, 2014) and interest in STEM (Marth & Bogner, 2019; Sansone, 2017; Virtanen et al., 2015) with higher values for males, e.g., in a previous study (Cheryan et al., 2017), males had higher interest in computer science, engineering, and physics. However, this association of gender and interest in STEM with females scoring lower on interest in STEM disappears when controlling for technical socialization. Therefore, the present study adds to the previous ones but also contradicts previous findings by adding that the females are equally interested in STEM as boys are when their technical socialization is similar. Gender also was related to the choice of degree program with fewer females enrolling in technology subjects than males.

Females share better grades in STEM subject than males but are later underrepresented as STEM teachers. The shortage in STEM teachers could easily be solved when obstacles in career choices, i.e., the sexism, is abandoned. Further research is needed to investigate the study choice motives – here, as shown by Engström (2018), females share different values than males: female engineering students emphasize altruistic values, e.g., contributing to a better society and environment, while male engineering students emphasize practical and technical aspects of the profession (Engström, 2018) and it is yet unclear how these value orientations are related to technical socialization. Technical socialization was strongly gender-dependent, also in line with previous research (Aguillon et al., 2020; Brämer, 2019; Gorlov, 2009; van der Vleuten et al., 2018). The "missing women phenomenon" of women in STEM subjects in China is attributed to women's lower STEM achievement motivation (Yang & Gao, 2021). However, to our best knowledge, there was no previous study highlighting the relation of technical socialization and interest in STEM.

Limitations

Currently, the prevailing gender norms are rather reinforced than challenged (Leaper & Brown, 2018), and these norms are the major obstacle to gender equity in interest in STEM. Sexism is present from childhood to adulthood (Dasgupta & Stout, 2014). Therefore, sexism may also be at work in the present research and the respondents' answers are influenced by these prevailing gender norms, because these norms are incorporated in the individuals' gender identity. However, the authors' intention was to present their research in a way that does not reinforce sexism but gives way to gender equity. Our approach is reducing the gender gap through action. At this point, however, it is important to note that there is always a risk that this will reinforce rather than challenge prevailing gender norms and stereotypes.

The present study implemented a quantitative design with multiple study groups. However, there are some limitations for the methods used. The sample sizes were different for each of the four degree programs and the gender composition differed. This speaks for the ecological validity of the data, because the engineering, females are scarce. However, the design could have profited from a more balanced sample regarding gender. Further, this is a cross-sectional study. A longitudinal study would provide valuable causal information in order to draw more reliable conclusions. Moreover, the survey implemented self-report questions and the information provided by students may deviate. No claim of non-bias can be made at this point.

Structural inequities are challenging and women are familiar with these challenges throughout their educational and career pathways, as identified by Petroff et al. (2021) via in-depth interviews. While other researchers have taken a qualitative approach to focus on the multi-faceted challenges, this would have been interesting to pursuit, but was not the aim of the present quantitative study.

Finally, the results may not easily be transferred to other German federal states or other countries, because, in Germany, technology education is only fragmentarily implemented. The results shown here can only be transferred to other school settings after cautious inspection of the curriculum subject technology education. There are also different ideas about what technology is and which technical activities are important. Historically, technology has often been associated with a male domain, so the respondents may also have been influenced by prevailing gender norms when answering the questions.

Outlook

The present study suggests ways to reduce the gender gap in technology education and engineering. Most importantly, the present study found that it is not the students' gender, but the different technical socialization of females and males which hinders that more females take on a STEM career. This information could be used for attracting more students and especially more female students to a technical profession. However, this is not an easy task because different agents in a child's life, e.g., parents, siblings, peers, and teachers, need to change their views on the present normative roles for females and males.

The present study also found that the choice of degree program has an influence on the student's subsequent interest in STEM. The research findings could therefore help to counteract gender-dependent study choice behavior. In detail, factors that promote the choice of study are technical socialization, the choice of technology as school subject and previous experience in the industrial/technical occupational field (vocational training). The gender gap in technology skills in Germany as well as in the rest of the world can therefore not be reduced with individual model projects for the partial promotion of girls, but rather with technical socialization for every child with binary or non-binary gender identity and compulsory technology education for all children. The implementation of technology education as a nationwide school subject in Germany from primary to secondary level could certainly reduce individual differences. Such approaches, raising awareness for technology education at an early stage, are a logical option. This action could promote more technology teachers of every gender. In addition, parents and people in the education sector should be sensitized to the topic in order to strengthen the self-concept of girls in the field of STEM and thus lower the barriers. Moreover, professionals should be made aware of the glass ceiling in technical careers for females and offered ways to mitigate it (Fernandez & Campero, 2017).

In German-speaking countries, there are a number of career choice projects “Girls’ Day” (https://www.girls-day.de/), “Girls and Technology” (MUT – Mädchen und Technik; www.mut.co.at), “Women and Technology” (FiT – Frauen in Technik; www.ams.at/fit), “Girls Digital Camps” (https://girls-dc-es.de/). These projects still fail to eradicate the sexism in STEM. Out-of-school learning can be effective in increasing interest in female students because is a novel approach to reduce the gender gap (Wünschmann et al., 2017). Pupils with no technical socialization need hands-on experiences in technology. When their teachers are non-specialists, outreach labs can somewhat substitute these first-hand experiences and may spark interest for technology and thus may make teacher training students more likely to choose a minor (major) subject in technology.

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Declarations

Conflict of interest The authors declare no competing financial interests.

Availability of data and material The data that support the findings of this study are available from the corresponding author, S.G., upon reasonable request.

Ethical approval The study was approved by the ethics commission of the University of Education Heidelberg.

Consent to participate Informed consent was obtained from all participants. Participation was collected anonymously and is analyzed for scientific research purposes only.

Consent for publication Both authors gave consent for the publication. The consent for publication is signed by both authors.

References

acatech, & VDI. (2009). *Nachwuchsbarometer Technikwissenschaften [newcomer in technology]*. Ley + Wiegandt.

acatech (Ed.). (2011). *Acatech berichtet und empfiehlt: Vol. 5. Monitoring von Motivationskonzepten für den Techniknachwuchs [Monitoring of motivational concepts for the next generation of technical newcomers]*. Springer. https://doi.org/10.1007/978-3-642-15921-3

acatech, & Körber Stiftung. (2014). *MINT Nachwuchsbarometer 2014*. Gutenberg Beuys Feindruckerei.

acatech, & Körber Stiftung. (2020). *MINT Nachwuchsbarometer 2020 [STEM newcomer report 2020]*. Gutenberg Beuys Feindruckerei.

acatech, & Körber Stiftung. (2021). *MINT Nachwuchsbarometer 2021 [STEM newcomer report 2021]*. Gutenberg Beuys Feindruckerei.

Aeschlimann, B., Herzog, W., & Makarova, E. (2015). Frauen in MINT-Berufen: Retrospektive Wahrnehmung des mathematisch-naturwissenschaftlichen Unterrichts auf der Sekundarstufe I [Women in STEM careers: Retrospective perceptions of mathematics and science education on the lower secondary level]. *Zeitschrift Für Bildungsforschung, 5*(1), 37–49. https://doi.org/10.1007/s35834-014-0111-y

Aguillon, S. M., Siegmund, G.-F., Petipas, R. H., Drake, A. G., Cotner, S., & Ballen, C. J. (2020). Gender differences in student participation in an active-learning classroom. *CBE Life Sciences Education*. https://doi.org/10.1187/cbe.19-03-0048

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching, 47*(5), 564–582. https://doi.org/10.1002/tea.20353

Augustin-Dittmann, S., & Gotzmann, H. (2015). Fazit und Empfehlungen: Was macht MINT-Projekte für Schülerinnen erfolgreich? [Conclusions and recommendations: What makes STEM projects successful for female pupils?]. In S. Augustin-Dittmann & H. Gotzmann (Eds.), *MINT gewinnt Schülerinnen [STEM wins pupils]* (pp. 127–142). Springer Fachmedien.

Baaser, H. (2021). Simulationstechniken in der Produktentstehung. Anregungen für den Übergang von Schule zu MINT-Studium [Simulation technologies in product design. Ideas for the transition to tertiary STEM-education]. *MNU-Jounal, 74*(4), 332–336.

Beckmann, J. (2021). Gendered career expectations in context: The relevance of normative and comparative reference groups. *British Journal of Sociology of Education, 42*(7), 968–988. https://doi.org/10.1080/01425692.2021.1914547

Bell, D., Wooff, D., McLain, M., & Morrison-Love, D. (2017). Analysing design and technology as an educational construct: An investigation into its curriculum position and pedagogical identity. *The Curriculum Journal, 28*(4), 539–558. https://doi.org/10.1080/09585176.2017.1286995

BMBF. (2018). *Berufsbildungsbericht [Vocational training report]*. Zarbock.

Brämer, S. (2019). Einflussfaktoren auf die technische Berufs- und Studienwahl von jungen Frauen in Sachsen-Anhalt [Factors influencing technical careers and study choices of young women in Saxony-Anhalt]. In F. Gramlinger, C. Iller, A. Ostendorf, A. Schmid, & K. Tafner (Eds.), *Beiträge zur 6. Berufsbildungsforschungskonferenz (BBFK). Bildung = Berufsbildung?!* (pp. 339–351). wbv.

Bührer, S., & Schraudner, M. (2006). *Gender-Aspekte in der Forschung. Wie können Gender-Aspekte in Forschungsvorhaben erkannt und bewertet werden? [Gender aspects in research. How can gender aspects be recognised and evaluated in research projects?]*. Fraunhofer.

Cacioppo, J. T., & Petty, R. E. (1982). The need for cognition. *Journal of Personality and Social Psychology, 42*(1), 116–131. https://doi.org/10.1037/0022-3514.42.1.116

Cheryan, S., Ziegler, S. A., Montoya, A. K., & Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychological Bulletin, 143*(1), 1–35. https://doi.org/10.1037/bul0000052

IBM Corp. (2019). *IBM SPSS Statistics for Windows, Version 26.0* [Computer software]. IBM Corp.

Dasgupta, N., & Stout, J. G. (2014). Girls and women in science, technology, engineering, and mathematics. *Policy Insights from the Behavioral and Brain Sciences, 1*(1), 21–29. https://doi.org/10.1177/2372732214549471

DIHK. (2019). *Konjunktur auf Talfahrt [Economy on a downward trend]: DIHK-Konjunkturumfrage Herbst 2019 [DIHK-Economic-Survey Fall 2019]*. Deutscher Industrie- und Handelskammertag.

Engström, S. (2018). Differences and similarities between female students and male students that succeed within higher technical education: Profiles emerge through the use of cluster analysis. *International Journal of Technology and Design Education, 28*(1), 239–261. https://doi.org/10.1007/s10798-016-9374-z

Fernandez, R. M., & Campero, S. (2017). Gender sorting and the glass ceiling in high-tech firms. *ILR Review, 70*(1), 73–104. https://doi.org/10.1177/0019793916668875

Finsterwald, M., Schober, B., Jöstl, G., & Spiel, C. (2012). Motivation und Attributionen: Geschlechtsunterschiede und Interventionsmöglichkeiten [Motivation and attributions: Gender differences and possibilities for intervention]. In H. Stöger, A. Ziegler, & M. Heilemann (Eds.), *Mädchen und Frauen in MINT. Bedingungen von Geschlechtsunterschieden und Interventionsmöglichkeiten [Girls and women in STEM. Conditions of gender differences and possibilities of intervention]* (pp. 193–212). Lit.

Foley, D. J. (2009). *Characteristics of doctoral scientists and engineers in the United States: 2006*. National Science Foundation.

Foley, D. J., Selfa, L. A., & Grigorian, K. H. (2019). *Number of Women with U.S. Doctorates in Science, Engineering, or Health Employed in the United States More Than Doubles since 1997*. National Center for Science and Engineering Statistics.

Freeman, N. K. (2007). Preschoolers' perceptions of gender appropriate toys and their parents' beliefs about genderized behaviors: miscommunication, mixed messages, or hidden truths? *Early Childhood Education Journal, 34*(5), 357–366. https://doi.org/10.1007/s10643-006-0123-x

Gabay-Egozi, L., Nitsche, N., & Grieger, L. (2022). In Their footsteps or shadow? gender differences in choosing a STEM major as a function of sibling configuration and older sibling's gender and math ability. *Sex Roles, 86*(1–2), 106–126. https://doi.org/10.1007/s11199-021-01255-0

Gerlitz, J.-Y., & Schupp, J. (2005). *Zur Erhebung der Big-Five-basierten Persönlichkeitsmerkmale im SOEP [On the survey of the Big Five-based personality traits in the SOEP]* (Research Notes 4). Deutsches Institut für Wirtschaftsforschung.

Gomez Soler, S. C., Abadía Alvarado, L. K., & Bernal Nisperuza, G. L. (2020). Women in STEM: Does college boost their performance? *Higher Education, 79*(5), 849–866. https://doi.org/10.1007/s10734-019-00441-0

Goreth, S. (2021). Rollenspezifische Unterschiede bei Lehrpersonen im Fachbereich Technik und Textil – Ergebnisse einer Befragung von Lehrpersonen in Tirol. *MNU-Journal, 6*, 462–467.

Gorlov, V. (2009). *Warum gibt es kaum Ingenieurinnen? Gründe für eine geschlechts(un)spezifische Berufswahl. Deutschland und Schweden im Vergleich [Why are there hardly any female engineers? Reasons for a gender (un)specific career choice. Germany and Sweden in comparison]*. Zugl.: Bamberg, Otto-Friedrich-Universität Bamberg, Diplomarbeit. *Bamberger Beiträge zur Soziologie: Vol. 4*. University of Bamberg Press.

Haas, R., Maja Jeretin-Kopf, M., & Wiesmüller, C. (Eds.). (2018). *Technische Kreativität: Interdisziplinäre Aspekte der kreativen Technikgestaltung [Technical Creativity: Interdisciplinary Aspects of Creative Technology Design]*. Steinbeis-Edition.

Hall, C. W., Kauffmann, P. J., Wuensch, K. L., Swart, W. E., DeUrquidi, K. A., Griffin, O. H., & Duncan, C. S. (2015). Aptitude and personality traits in retention of engineering students. *Journal of Engineering Education, 104*(2), 167–188. https://doi.org/10.1002/jee.20072

Hallström, J., Elvstrand, H., & Hellberg, K. (2015). Gender and technology in free play in Swedish early childhood education. *International Journal of Technology and Design Education, 25*(2), 137–149. https://doi.org/10.1007/s10798-014-9274-z

Heublein, U., & Schmelzer, R. (2018). *Die Entwicklung der Studienabbruchquoten an den deutschen Hochschulen. Berechnungen auf Basis des Absolventenjahrgangs 2016 [The development of drop-out rates at German universities. Calculations based on the graduating class of 2016]*. DZHW-Projektbericht.

Hill, C., Corbett, C., & St. Rose, A. (2010). *Why So Few? Women in Science, Technology, Engineering, and Mathematics*. American Association of University Women.

ITEA. (2006). *Technological Literacy for All: A Rationale and Structure for the Study of Technology*. International Technology Education Association.

Jann, B., & Hupka-Brunner, S. (2020). Warum werden Frauen so selten MINT-Fachkräfte? Zur Bedeutung der Differenz zwischen mathematischen Kompetenzen und Selbstkonzept [Why do women so rarely become STEM professionals? On the importance of the difference between mathematical competences and self-concept]. *Swiss Journal of Educational Research, 42*(2), 391–413. https://doi.org/10.24452/sjer.42.2.6

Landesinstitut für Schulentwicklung. (2016). *Industrie 4.0 [Industry 4.0]: Umsetzung im Unterricht [Implementation in the classroom]*.

Leaper, C., & Brown, C. S. (2018). Sexism in childhood and adolescence: Recent trends and advances in research. *Child Development Perspectives, 12*(1), 10–15. https://doi.org/10.1111/cdep.12247

Legewie, J., & DiPrete, T. A. (2014). The high school environment and the gender gap in science and engineering. *Sociology of Education, 87*(4), 259–280. https://doi.org/10.1177/0038040714547770

Marth, M., & Bogner, F. X. (2019). Monitoring a gender gap in interest and social aspects of technology in different age groups. *International Journal of Technology and Design Education, 29*(2), 217–229. https://doi.org/10.1007/s10798-018-9447-2

Mawson, B. (2007). Factors affecting learning in technology in the early years at school. *International Journal of Technology and Design Education, 17*(3), 253–269. https://doi.org/10.1007/s10798-006-9001-5
McClure, J., Meyer, L. H., Garisch, J., Fischer, R., Weir, K. F., & Walkey, F. H. (2011). Students' attributions for their best and worst marks: Do they relate to achievement? *Contemporary Educational Psychology, 36*(2), 71–81. https://doi.org/10.1016/j.cedpsych.2010.11.001
Moè, A., Jansen, P., & Pietsch, S. (2018). Childhood preference for spatial toys. Gender differences and relationships with mental rotation in STEM and non-STEM students. *Learning and Individual Differences, 68*, 108–115. https://doi.org/10.1016/j.lindif.2018.10.003
Muthén, L. K., & Muthén, B. O. (1998–2012). *Mplus user's guide. Seventh edition*. Muthén & Muthén.
Nürnberger, M., Nerb, J., Schmitz, F., Keller, J., & Sütterlin, S. (2016). Implicit gender stereotypes and essentialist beliefs predict preservice teachers' tracking recommendations. *The Journal of Experimental Education, 84*(1), 152–174. https://doi.org/10.1080/00220973.2015.1027807
Petroff, A., Sáinz, M., & Arroyo, L. (2021). A multilevel qualitative perspective to gendered life course, socialization, and STEM trajectories among emerging adults in Spain. *Emerging Adulthood*. https://doi.org/10.1177/21676968211021678
Pohlmann, B., & Möller, J. (2010). Fragebogen zur Erfassung der motivation für die Wahl des Lehramtsstudiums [Questionnaire to assess motivation for choosing a teacher training programme] (FEMOLA). *Zeitschrift Für Pädagogische Psychologie, 24*(1), 73–84. https://doi.org/10.1024/1010-0652/a000005
Praxis [Contributions to school development. Gender-sensitive Education and Upbringing in Schools: Fundamentals - Fields of Action - Practice] (1st ed., pp. 17–24). Waxmann.
Preckel, F. (2014). Assessing need for cognition in early adolescence. *European Journal of Psychological Assessment, 30*(1), 65–72. https://doi.org/10.1027/1015-5759/a000170
Rendtorff, B. (2017). Was ist eigentlich ‚gendersensible Bildung' und warum brauchen wir sie? [What actually is 'gender-sensitive education' and why do we need it?]. In I. Glockentöger & E. Adelt (Eds.), *Beiträge zur Schulentwicklung. Gendersensible Bildung und Erziehung in der Schule: Grundlagen – Handlungsfelder*
Retelsdorf, J., Bauer, J., Gebauer, S. K., Kauper, T., & Möller, J. (2014). Erfassung berufsbezogener Selbstkonzepte von angehenden Lehrkräften [Assessment of career-related self-concepts of trainee teachers] (ERBSE-L). *Diagnostica, 60*(2), 98–110. https://doi.org/10.1026/0012-1924/a000108
Ropohl, G. (2009). *Allgemeine Technologie. Eine Systemtheorie der Technik [General Technology. A Systems Theory of Technology]*. Universitätsverlag Karlsruhe.
Sachs, B. (1987). Frauen und Technik – Mädchen im Technikunterricht [Women and Technology - Girls in Technics]. *Zeitschrift Für Technik Im Unterricht, 46*, 5–14.
Salchegger, S., Glaeser, A., & Pareiss, M. (2019). Top in Physik, aber trotzdem kein MINT-Beruf? Geschlechtsspezifische Berufsaspirationen von Spitzenschülerinnen und -schülern. In F. Gramlinger, C. Iller, A. Ostendorf, K. Schmid, & G. Tafner (Eds.), *Bildung = Berufsbildung?!* (pp. 367–380). wbw.
Sansone, D. (2017). Why does teacher gender matter? *Economics of Education Review, 61*, 9–18.
Sassler, S., Glass, J., Levitte, Y., & Michelmore, K. M. (2017). The missing women in STEM? Assessing gender differentials in the factors associated with transition to first jobs. *Social Science Research, 63*, 192–208. https://doi.org/10.1016/j.ssresearch.2016.09.014
Schmader, T., & Block, K. (2015). Engendering identity: Toward a clearer conceptualization of gender as a social identity. *Sex Roles, 73*(11–12), 474–480. https://doi.org/10.1007/s11199-015-0536-3
Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK). *Journal of Research on Technology in Education, 42*(2), 123–149. https://doi.org/10.1080/15391523.2009.10782544
Schuhen, M., & Schürkmann, S. (2015). Inwieweit nehmen Gymnasiasten Rahmenbedingungen in ihre Entscheidung bei der Berufs- und Studienwahl auf? [To what extent do grammar school pupils take framework conditions into account when deciding on their career and study choices?]. *Zeitschrift Für Ökonomische Bildung, 3*(3), 75–94.
Solga, H., & Pfahl, L. (2009). Doing gender im technisch-naturwissenschaftlichen Bereich. In J. Milberg (Ed.), *Förderung des Nachwuchses in Technik und Naturwissenschaft [Promoting young talent in technology and science]: Beitrage zu den zentralen Handlungsfeldern [Contributions to the central fields of action]* (pp. 155–218). Springer.
Statistisches Landesamt Baden-Württemberg. (2019). *Statistikabfrage zum Wahlverhalten von Schüler*innen in Baden-Württemberg [Statistical survey on the choice behaviour of pupils in Baden-Württemberg].*
Sultan, U., Axell, C., & Hallström, J. (2019). Girls' engagement with technology education: A scoping review of the literature. *Design and Technology Education: An International Journal, 24*(2), 20–41.

Sultan, U., Axell, C., & Hallström, J. (2020). Technical or not? Investigating the self-image of girls aged 9 to 12 when participating in primary technology education. *Design and Technology Education: An International Journal, 25*(2), 175–191.
Sutterlüti, E. (2013). Frauen und Technik! Männer und Textil? [Women and technology! Men and textile?]. In J. Seiter (Ed.), *Schulheft: Vol. 150. ein/fach Technik. Plädoyers zur technischen Bildung für alle [one/subject technology. Pleas for technical education for all]* (pp. 98–105). Studienverlag.
Swafford, M., & Anderson, R. (2020). Addressing the gender gap: women's perceived barriers to pursuing STEM careers. *Journal of Research in Technical Careers, 4*(1), 61. https://doi.org/10.9741/2578-2118.1070
Systems, A. (2012). *Adobe Illustrator, Version CS6*. [Computer software].
Tenberg, R. (2016). Editorial: How can we get technology taught in schools? *Journal of Technical Education, 4*(1), 1–10.
Theuerkauf, W. E. (2013). *Prozessorientierte Technische Bildung. Ein transdisziplinäres Konzept [Process-oriented technical education. A transdisciplinary concept]*. Peter Lang Verlag. https://doi.org/10.3726/978-3-653-02809-6
U.S. Department of Education. (2017). *Reimagining the Role of Technology in Education: 2017 National Education Technology Plan Update*. Office of Educational Technology. http://tech.ed.gov
van der Vleuten, M., Steinmetz, S., & van de Werfhorst, H. (2018). Gender norms and STEM: The importance of friends for stopping leakage from the STEM pipeline. *Educational Research and Evaluation, 24*(6–7), 417–436. https://doi.org/10.1080/13803611.2019.1589525
van Tuijl, C., & van der Molen, J. H. W. (2016). Study choice and career development in STEM fields: An overview and integration of the research. *International Journal of Technology and Design Education, 26*(2), 159–183. https://doi.org/10.1007/s10798-015-9308-1
Virtanen, S., Räikkönen, E., & Ikonen, P. (2015). Gender-based motivational differences in technology education. *International Journal of Technology and Design Education, 25*(2), 197–211. https://doi.org/10.1007/s10798-014-9278-8
Wang, M.-T., & Degol, J. (2013). Motivational pathways to STEM career choices: using expectancy-value perspective tounderstand individual and gender differences in STEM fields. *Developmental Review, 33*(4), 303–340. https://doi.org/10.1016/j.dr.2013.08.001
Weisberg, Y. J., Deyoung, C. G., & Hirsh, J. B. (2011). Gender differences in personality across the ten aspects of the big five. *Frontiers in Psychology, 2*, 178. https://doi.org/10.3389/fpsyg.2011.00178
Wirtz, M. A. (2013). *Dorsch - Lexikon der Psychologie* (16th ed.). Hans Huber.
Wünschmann, S., Wüst-Ackermann, P., Randler, C., Vollmer, C., & Itzek-Greulich, H. (2017). Learning achievement and motivation in an out-of school setting - visiting amphibians and reptiles in a zoo is more effective than a lesson at school. *Research in Science Education, 47*, 497–518. https://doi.org/10.1007/s11165-016-9513-2
Yang, X., & Gao, C. (2021). Missing women in stem in china: an empirical study from the viewpoint of achievement motivation and gender socialization. *Research in Science Education, 51*(6), 1705–1723. https://doi.org/10.1007/s11165-019-9833-0
Zinn, B. (2018). Editorial: The lack of teaching staff and new teacher training entrants in the industrial-technical subjects at vocational colleges. *Journal of Technical Education, 6*(2), 1–4.