education sciences

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Measuring Implicit STEM and Math Attitudes in Adolescents Online with the Brief Implicit Association Test

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Abstract: Despite societal efforts toward enhancing gender equality, females are still underrepresented in STEM (science, technology, engineering, mathematics). Prominent explanations draw on gender differences in attitudes about STEM (with females holding more negative attitudes than males), which result from the gender stereotype that STEM is a male domain. While a lot of research has focused on explicit attitudes, little is known about implicit attitudes toward STEM. The present research sought to examine implicit attitudes among adolescents, and how they relate to other STEM cognitions. We measured implicit attitudes about the STEM concept as a whole, and about math in particular. For this purpose, we developed two Brief Implicit Associations Tests (BIATs) and administered them online in a sample of adolescents (N = 517). We additionally measured a variety of self-reported motivational and social-psychological variables (interest, aspiration, self-concept of ability, and sense of belonging to the math and STEM community, respectively), which previous research has identified as factors contributing to the gender gap in STEM participation. Our findings confirm the reliability and validity of both the STEM BIAT and the Math BIAT. Moreover, implicit STEM attitudes predicted interest in and aspiration for STEM, self-concept of STEM ability, and sense of belonging to the STEM community. Similarly, implicit math attitudes predicted interest in and aspiration for math, and sense of belonging to the math community (but not self-concept of math ability). Our findings confirm that our novel online BIATs are efficient measurement tools of implicit attitudes in adolescents. Moreover, our findings underscore the significance of implicit attitudes in the STEM domain.

Keywords: implicit attitudes; STEM; mathematics; gender stereotypes

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Citation: Reichardt, R.; Rottmann, C.; Russo, L.; Emmerdinger, K.J.; Schirner, S. Measuring Implicit STEM and Math Attitudes in Adolescents Online with the Brief Implicit Association Test. *Educ. Sci.* **2023**, *13*, 899. https://doi.org/10.3390/educsci13090899

Academic Editors: Erin Mackenzie, Bernhard Ertl, Christine R. Starr, Silke Luttenberger and Manuela Paechter

Received: 6 June 2023
Revised: 2 September 2023
Accepted: 4 September 2023
Published: 6 September 2023

1. Introduction

Despite societal efforts toward enhancing gender equality, females are still underrepresented in the STEM domain, i.e., science, technology, engineering, and mathematics [1,2]. A tremendous amount of research has been devoted to understanding the factors determining the gender gap in STEM participation, identifying factors at the individual as well as the environmental level [3–6]. Importantly, gender gaps in STEM participation persist despite no or small gender gaps in STEM-related achievement [7–10]. Instead, cognitive, emotional, and motivational factors appear to play a major role. In particular, the stereotype that STEM is a male domain negatively affects females' attitudes about STEM, their self-concept of abilities in STEM, their STEM identity, and their sense of belonging to the STEM community, eventually influencing decisions to enter or leave STEM fields [6,11–16].

The present research focused on attitudes about STEM as an important factor contributing to the gender gap in STEM participation. We adopt the widespread definition of *attitude* as a global evaluation of an entity with some degree of favor or disfavor [17,18]. Attitudes are key determinants of motivation, decision-making, and behavior [19,20]. By and large, numerous studies demonstrate that females compared to males report more negative attitudes toward math and science [7,9,21–25]. Furthermore, math and science attitudes have been shown to be related to STEM choices and achievement [26–30].

Most research so far has focused on explicit or self-report measures of STEM attitudes and other cognitions. However, self-reports do not capture the entire spectrum of cognitions relevant to motivation and behavior. A tremendous amount of research in social psychology and beyond has shown that implicit attitudes and other implicit cognitions play an important role in motivation, behavior and decision-making (for a review, see [31]). At the same time, little is known about implicit STEM attitudes in adolescents who are at a stage in life where they are setting the course for their future professional careers. To fill this gap, the present research investigated implicit attitudes about STEM among adolescents and how they relate to other STEM cognitions.

1.1. Implicit Cognitions

In contrast to self-reported or explicit cognitions, implicit cognitions reflect automatic associations that are activated quickly and independently of goals [32,33]. Implicit cognitions are not easily accessible to introspection, and even if accessible, participants may not report them as such but adjust them based on their ideals, norms, and values. Both implicit and explicit cognitions contribute to motivation, behavior, and decision-making, yet under different conditions [20,34,35]. For instance, implicit attitudes about a political issue have been shown to better predict future decisions among undecided voters than explicit attitudes [36]. With respect to STEM, implicit gender stereotypes have been shown to predict women's commitment and fit in STEM [37]. In sum, a vast amount of research has shown the relevance of implicit cognitions in predicting a variety of outcomes [31,38]. Against this background, it seems reasonable that implicit cognitions contribute to the gender gap in STEM participation. Previous research on implicit STEM cognitions can be distinguished based on (1) the domain (math, science, STEM, etc.), (2) the type of association (stereotypes, attitudes, etc.), and (3) the age of the population (children, adolescents, adults).

To begin with, implicit stereotypes about math or science as male domains are prevalent around the world, yet with considerable variability between countries [12,39–41]. Implicit math gender stereotypes have been observed not only among adults but also among adolescents [42,43] (but see [44]), and even among elementary school children [45]. Similarly, implicit physics gender stereotypes have been observed among adults [46] and adolescents [47]. Among females, implicit math gender stereotypes predicted more negative implicit attitudes about math [41,48], a lower self-reported self-concept of abilities [41,43], and worse math achievement [41,43,49]. Furthermore, among females, implicit math gender stereotypes as well as implicit science gender stereotypes predicted lower interest or participation in the respective domain [14,41,42,50,51].

Most relevant to the present research are findings on implicit attitudes about STEM. However, we are not aware of a study on implicit attitudes about the concept of STEM as a whole. So far, research has investigated implicit attitudes about specific STEM-subjects, such as math or physics. In particular, implicit attitudes about math or physics were related to participant gender, with females exhibiting more negative implicit attitudes than males [41,47,48,52]. Gender differences in implicit attitudes about math have been observed already among elementary school children [52], and gender differences in implicit attitudes about physics have been observed among adolescents [47]. Implicit attitudes about math were related to interest and participation in math [41], self-concept of math abilities [41], and math achievement [41,48,52].

To summarize, implicit stereotypes and attitudes have been shown to play a pivotal role in STEM-related cognitions, motivation, and behavior. While there has been extensive research on implicit gender stereotypes about science or math as well as implicit attitudes about math or physics, we are not aware of a study on implicit attitudes about the concept of STEM as a whole. Moreover, most studies investigated implicit cognitions in adults, and the few studies that did examine implicit cognitions in children or adolescents focused on specific school subjects such as math or physics.

1.2. The Present Research

The main objective of the present research was to investigate implicit attitudes about STEM among secondary school students and their relation to other STEM cognitions. A better understanding of implicit attitudes about STEM in this population is essential for several reasons. First, previous research shows that interest in STEM rapidly declines throughout secondary school [53], making it especially important to learn more about implicit STEM attitudes and their contribution to STEM motivational factors in this age group. Second, the concept of STEM is omnipresent in education, and students are confronted with several STEM-related choices before and during secondary school in the German education system. Transition from elementary to secondary school already requires setting the course for future STEM-related educational options (i.e., selecting a school that offers a STEM profile). Depending on the school type, students at a higher grade level (e.g., seventh grade) can choose whether they want to intensify STEM subjects or other subjects (e.g., languages). Furthermore, students in secondary school can often choose to participate in extracurricular programs regarding STEM. Third, many intervention programs that aim at increasing female participation in STEM address the overarching concept of STEM, that is, they do not focus on single (school) subjects, but on various STEM domains and interdisciplinary aspects [54,55]. An instrument to capture implicit attitudes about STEM in school students would thus be a valuable evaluation tool for such programs. As STEM is an important concept in our society and education system, it is essential to better understand attitudes about this concept in school students and how they relate to other STEM cognitions.

Related to our main objective of investigating implicit STEM attitudes, our research had a further methodological goal. We sought to develop a novel measure of implicit STEM attitudes and evaluate whether this measure yields reliable and valid results when adolescents complete it online on a voluntary basis, at a location and time of their own choice. Previous research on implicit attitudes has mostly used the Implicit Association Test (IAT) [56]. In the IAT, participants rapidly classify stimuli belonging to four categories using two response keys. For instance, in a math-language-attitude IAT, participants classify stimuli belonging to the categories *math*, *language*, *positive*, and *negative*. They see one stimulus at a time on the computer screen (e.g., a math-related word such as “number”, a language-related word such as “word”, a positive word such as “love”, or a negative word such as “hate”). In one block, they use one response key (e.g., right key) for math and positive words, and the other response key (e.g., left key) for language and negative words. In the other block, they use one response key for language and positive words, and the other response key for math and negative words. The difference in the average response latencies of the two blocks represents the extent to which math or language is associated with positivity or negativity. For instance, faster responses in the math/positive–language/negative block than in the language/positive–math/negative block indicate positive associations with math relative to language.

Completion of the IAT is cognitively demanding and lengthy. As such, it is a suboptimal instrument when administered online on a voluntary basis in the age group of adolescents because it may result in large dropout rates. Previous research on implicit cognitions in underaged participants has been conducted in the lab and has used a simplified variant of the IAT with fewer exemplar stimuli to classify [47,52]. While reducing the number of stimuli is appropriate when the IAT assesses attitudes about a single subject such as math or physics, it is not suitable for measuring attitudes about a multifaceted construct such as STEM.

To develop a measurement instrument that adequately captures the multifaceted construct of STEM and is, at the same time, short and appealing for adolescents, we adapted the Brief Implicit Association Test (BIAT) [57]. The BIAT is a variant of the IAT that is easier and takes less time to complete than the IAT because the classification task is simplified, while, at the same time, the number of different exemplar stimuli is retained. Importantly, the BIAT has comparable psychometric properties in terms of reliability and validity as the IAT, as demonstrated in several adult samples [58]. However, the BIAT has not yet been used with underaged participants. Thus, it remains to be shown that the BIAT is a reliable and valid instrument in this age group.

To evaluate the BIAT as a measurement instrument in our target group, we implemented two BIATs that we aimed to compare, one BIAT assessing implicit attitudes about STEM and one BIAT assessing implicit attitudes about math. We know from previous research that implicit attitudes about math can be measured in underaged participants with a child-friendly IAT [52]. Therefore, we expect similar results with our novel Math BIAT. We will further investigate whether our novel STEM BIAT yields comparable results.

First, we aim to evaluate the psychometric properties of our Math and STEM BIATs. To evaluate the reliability of the BIATs we analyzed internal consistency. To evaluate the construct validity of the BIATs, we analyzed correlations with self-report measures of attitudes about math or STEM, respectively. Implicit and self-report measures of attitudes are thought to assess distinct, but related constructs [59]. According to previous research on the relation between implicit and explicit attitude measures, we should find small-to-medium-sized correlations [31].

Second, we examine the predictive validity of the BIATs by investigating their relations to other math- or STEM-related measures, respectively. Based on what has been observed with respect to implicit math attitudes [41,52], we expect implicit math attitudes to be related to interest in math, to aspiration in math, and to self-concept of math abilities. In a similar vein, we expect implicit STEM attitudes to be related to interest in STEM, to aspiration in STEM, and to self-concept of STEM abilities. We additionally examine whether implicit attitudes are related to sense of belonging to the respective community. Recent research suggests that gender stereotypes lead to a lower sense of belonging to the STEM community among females, which contributes to lower participation rates in females [6,60–65]. To our knowledge, the relation between sense of belonging and implicit attitudes has not yet been studied. Therefore, we seek to provide new evidence on a potential relation between these constructs. We expect that implicit math attitudes are related to sense of belonging to the math community. In a similar vein, implicit STEM attitudes should be related to sense of belonging to the STEM community.

2. Methods

The study was implemented and presented online using the PsyToolkit platform [66,67]. We report all manipulations, measures, and exclusions. Materials are available at https://osf.io/9sz32 (accessed on 26 May 2023).

2.1. Design

Participants completed either the Math BIAT or the STEM BIAT. They were randomly assigned to the BIAT conditions. Except for the BIAT, the conditions were identical, i.e., participants completed the same questionnaires in both conditions.

2.2. Participants

Participants were recruited on various online platforms, social media channels, and through personal contacts. The study was advertised as a study on attitudes about STEM. As compensation, participants could take part in a lottery of 50 vouchers for 10 EUR for an online shop of their choice. Informed consent was obtained from participants as well as their parents at the beginning of the study. The study was automatically terminated if consent was not given by either the participants or the parents.

N = 862 participants started the study after consent was provided. The participation criteria (1) aged between 10 and 17 years and (2) being a school student were assessed at the beginning of the study, and the study was terminated if participants did not meet the criteria. *N* = 844 participants met the participation criteria. *N* = 557 (66%) participants fully completed the study. Participants were excluded from the data analysis if they did not correctly answer the two attention check questions that were interspersed in the questionnaires (21 participants), if they indicated at the end of the study that they did not seriously answer the questions (five participants), if they were not yet in fifth grade (five participants), if there were technical problems (five participants), or if more than 10% of the responses in the BIAT were faster than 300 ms or slower than 10,000 ms (15 participants), which is the standard performance-based exclusion criterion in the BIAT [57,68]. We aimed for a total sample size of $N = 500$ ($N = 250$ per BIAT condition) to achieve sufficient power for correlational analyses [69]. The final sample size was $N = 517$ (262 participants completed the Math BIAT, and 255 participants completed the STEM BIAT). The demographics are shown in Tables 1 and 2.

Table 1. Numbers of participants.

Demographic Variables	Math BIAT Condition		STEM BIAT Condition	
	Male	**Female**	**Male**	**Female**
	104	**158**	**85**	**170**
School Type				
Comprehensive School	7	9	10	3
Lower-Track Sec. School [1]	0	2	1	0
Medium-Track Sec. School [1]	4	8	5	8
Higher-Track Sec. School [1]	89	136	66	149
Other	4	3	3	10
School Profile				
STEM profile	64	68	49	68
Language profile	19	33	17	41
Other or no profile	21	57	19	61
Subjects Taken				
Mathematics	104	158	85	170
Biology	100	146	81	159
Physics	93	126	66	135
Chemistry	85	115	60	117
Computer Science	73	108	54	112
German	104	158	85	170
English	104	158	82	168
French	48	86	34	87
Spanish	21	28	15	28
Latin	32	42	25	54

[1] Sec. = Secondary.

Table 2. Mean age and school grade level [1].

Demographic Variables	Math BIAT Condition		STEM BIAT Condition	
	Male	**Female**	**Male**	**Female**
Age	14.54 (2.02)	13.88 (2.17)	14.20 (2.20)	13.80 (2.11)
Grade level [2]	9.18 (2.16)	8.60 (2.11)	8.86 (2.21)	8.49 (2.13)

[1] Standard deviations are in parenthesis. [2] School grade level varied from 5th to 13th grade.

We examined whether demographic characteristics were distributed equally across the Math and STEM BIAT conditions. There was no significant association between condition and gender, $\chi^2(1) = 2.26$, $p = 0.133$. Participants did not differ between conditions in age, $t(515) = 1.10$, $p = 0.270$, $d = 0.10$ or grade level, $t(515) = 1.17$, $p = 0.245$, $d = 0.10$. There was no significant association between condition and school type (recoded as Higher-Track Secondary School vs. other), $\chi^2(1) = 0.25$, $p = 0.617$ or between condition and school profile (recoded as STEM profile vs. other/none), $\chi^2(1) = 1.05$, $p = 0.306$. In sum, the conditions did not differ in demographic variables.

Furthermore, we examined whether gender was associated with relevant demographic variables. Male participants were, on average, older than female participants, $t(515) = 2.82$, $p = 0.005$, $d = 0.26$. Correspondingly, male participants were, on average, in a higher grade level than female participants, $t(515) = 2.53$, $p = 0.012$, $d = 0.23$. There was no significant association between gender and school type (recoded as Higher-Track Secondary School vs. other), $\chi^2(1) = 2.25$, $p = 0.133$. However, there was a significant association between gender and school profile, $\chi^2(1) = 16.13$, $p < 0.001$. There were more male participants than expected and fewer female participants than expected in the STEM profile.

2.3. Procedure

Participants first answered demographic questions about their age, whether they were school students, the school type (response options were four different types of German secondary schools and other, see Table 1), the school profile if any (response options were language-oriented, STEM-oriented, and other), their grade level, and their gender. Then, participants were informed about the meaning of the acronym STEM (in German MINT) and that the STEM subjects in school were mathematics, computer science, biology, physics, and chemistry. They were told that some of the following questions would refer to STEM subjects, while other questions would refer to language subjects (e.g., German, Latin, English, French, Spanish). We selected the languages that are typically taught at secondary school in Germany. Participants were asked to indicate which of the following subjects they were currently taking or had taken before in school (mathematics, computer science, biology, physics, chemistry, German, Latin, English, French, Spanish).

Afterward, participants completed self-report measures on interest, aspiration, self-concept of abilities, attitudes, feeling thermometers, and feelings of belonging (for details see Section 2.4). Then, participants were randomly assigned to the BIAT condition (Math BIAT vs. STEM BIAT), with the constraint that gender was balanced across BIAT conditions.

After completion of the BIAT, participants could enter comments on the study, and they were asked to indicate whether they had seriously answered all question. Finally, participants were informed about the procedure of the lottery. To take part in the lottery, they were asked to enter a self-generated code that would be stored separately from their data to ensure anonymity of the study data and to send an E-Mail with the code and their name to the researcher.

2.4. Materials

2.4.1. Self-Report Measures

Interest in STEM and interest in languages were assessed with respect to the school subjects of mathematics, computer science, biology, physics, chemistry, German language, Latin, English, French, and Spanish [55,70]. A sample item is "Please indicate the extent to which you are interested in mathematics." Participants indicated their interest on a 6-point Likert scale from (*no interest at all*) to (*very strong interest*). For STEM-related analyses, responses to the STEM subjects were averaged to a STEM-interest scale ($\alpha = 0.71$), and responses to the language subjects were averaged to a language-interest scale ($\alpha = 0.62$).

Aspiration for STEM and aspiration for languages were assessed with respect to the subselection of school subjects that participants were currently taking (out of the school subjects mathematics, computer science, biology, physics, chemistry, German, Latin, English, French, and Spanish). For each of the subjects that participants were currently taking, they were asked "to specify the grade with which they would be satisfied in their next school report" [71]. The German grading system ranges from 1 (highest grade) to 6 (lowest grade). For STEM-related analyses, responses to the STEM subjects were averaged to a STEM-aspiration scale, and responses to the language subject were averaged to a language-aspiration scale. Because the subselection of school subjects, which comprised the STEM-aspiration and language-aspiration scales, respectively, differed between participants, internal consistency scores cannot be calculated across all participants.

Self-concept of abilities was assessed with respect to STEM abilities in general, as well as with respect to mathematics in particular. To this end, we used an adapted four-item scale version of the *belief in one's own abilities* scale [71,72]. The items were presented as 6-point bipolar Likert scale items with the poles labeled in item-specific ways ("I doubt that I am talented for the STEM subjects." vs. "I believe that I am talented for the STEM subjects."; "I am not sure whether I am good enough to succeed in the STEM subjects." vs. "I am sure that I am good enough to succeed in the STEM subjects."; "I don't have a lot of confidence in my STEM abilities." vs. "I have full confidence in my STEM abilities.", "When I get new learning material in the STEM subjects, I often think that I may not be able to understand it." vs. "When I get new learning material in the STEM subjects, I am usually able to understand it."). To assess the self-concept of mathematic abilities, we replaced the term *STEM subjects* with *mathematics.* The internal consistency was excellent for both the self-concept of STEM-ability scale ($\alpha = 0.92$) and the self-concept of mathematics-ability scale ($\alpha = 0.94$).

Attitudes were assessed with respect to STEM and languages in general, as well as with respect to mathematics and German in particular. To this end, we used an adapted three-item scale [48,73]. The items were presented as 6-point bipolar Likert scale items with the poles labeled in item-specific ways ("I don't favor the STEM subjects." vs. "I favor the STEM subjects."; "I don't like the STEM subjects at all." vs. "I like the STEM subjects a lot."; "The STEM subjects are absolutely boring." vs. "The STEM subjects are a lot of fun."). To assess attitudes toward the other domains, the term *STEM subjects* was replaced with *mathematics, language subjects*, and *German language*, respectively. Internal consistency was excellent for all attitude scales (STEM attitudes: $\alpha = 0.94$; math attitudes: $\alpha = 0.96$; language attitudes: $\alpha = 0.94$; German attitudes: $\alpha = 0.95$).

In addition to attitude scales, we administered feeling thermometers to assess the affective component of attitudes [48]. Feelings of unpleasantness/pleasantness were assessed with respect to the subselection of the school subjects, that participants were currently taking (out of the subjects mathematics, computer science, biology, physics, chemistry, German, Latin, English, French, and Spanish). Participants were asked to imagine that they were working on a task from each of these subjects. They should imagine the feelings they were experiencing while working on the task as vividly as possible. They gave their response on a slider scale ranging from *unpleasant* to *pleasant*. Responses were coded from 1 to 100. For STEM-related analyses, responses to the STEM subjects were averaged to a STEM-feeling thermometer scale, and responses to the language subjects were averaged to a language-feeling thermometer scale. Because the subselection of school subjects, which comprised the STEM-feeling thermometer and the language-feeling thermometer scales, respectively, differed between participants, internal consistency scores cannot be calculated across all participants.

Sense of belonging was assessed with respect to the STEM community and the math community. To this end, we adapted the Sense of Belonging Scale from Good et al. [62], following the German translation from Ladewig et al. [60]. We used a short four-item version ("I feel that I belong to the STEM people."; "I perceive myself as a member of the STEM community."; "I feel connected to the STEM people."; "I have the feeling that I am part of the STEM world."). Participants gave their responses on a 6-point Likert scale ranging from (*not at all*) to (*completely)*. To assess sense of belonging to the math community, the term *STEM* was replaced with *mathematics.* Internal consistency was excellent for both scales (sense of belonging to the STEM community: $\alpha = 0.95$; sense of belonging to the math community: $\alpha = 0.96$).

2.4.2. Implicit Measures

Like the IAT, the BIAT is a speeded classification task, in which participants are presented with stimuli—one at a time on the screen—belonging to one of four categories. Different from the IAT, participants focus on just two of the four categories when classifying the stimuli, which makes the task easier. For instance, when *STEM* and *good* are the focal categories, participants use the right response key for all stimuli belonging to the categories *STEM* or *good*, and the left response key for all other stimuli. Conversely, when *languages* and *good* are the focal categories, participants use the right response key for all stimuli belonging to the categories *languages* or *good,* and the left response key for all other stimuli. Like in the IAT, however, stimuli of all four categories are presented during a block, and the mapping of stimuli to response keys is the same as in the IAT. That is, in one block participants respond with the right key to *STEM* and *good* stimuli and with the left key to *languages* and *bad* stimuli. In the other block, they respond with the right key to *languages* and *good* stimuli and with the left key to *STEM* and *bad* stimuli. The BIAT is easier to complete than the IAT because participants must keep in working memory only the two focal categories (not all four categories as in the IAT). Furthermore, the BIAT needs fewer practice trials than the IAT, shortening total completion time.

The STEM BIAT was modeled after science IATs [12]. The stimuli of the STEM BIAT were the STEM subjects that are typically taught at German secondary schools (see Table 3). We used *languages* as the comparison category because this category is easy for adolescents to understand and because secondary schools in Germany offer a language profile as an alternative to the STEM profile. The stimuli of the category *languages* were the language subjects that are typically taught at German secondary schools. The attribute dimensions were *good* and *bad* as in similar attitude IATs [47,52,73]. We used the standard procedure of the BIAT [57,68] and adapted the instructions and the practice block to make the task easier for our age group of adolescents. Participants were told that their task was to decide as quickly as possible whether a word presented in the center of the screen matched a category presented at the top of the screen. They were shown several example screens (e.g., Does "dog" match the category "animal"?). They were told to press the right-hand key if the word matched the category (focal category), and the left-hand key if the word did not match the category (nonfocal category). The response keys were L and A on a QWERTZ keyboard.

Table 3. Category labels and stimuli presented in the STEM and Math BIATs.

Category Labels (English Translation)	Stimuli (English Translation)	Category Labels (Original German)	Stimuli (Original German)
STEM	Mathematics Biology Chemistry Physics Computer Science	MINT	Mathematik Biologie Chemie Physik Informatik
Languages	German Latin English French Spanish	Sprachen	Deutsch Latein Englisch Französisch Spanisch
Mathematics	Numbers Compute Summate Multiply Geometry	Mathematik	Zahlen Rechnen Addieren Multiplizieren Geometrie
German	Words Verbs Read Orthography Poem	Deutsch	Wörter Verben Lesen Rechtschreibung Gedicht
Good	Happy Love Laughing Pleasure Wonderful	Gut	Glücklich Liebe Lachen Freude Wundervoll
Bad	Agony Nasty Awful Terrible Horrible	Schlecht	Qual Übel Schrecklich Grausam Scheußlich

Participants first completed a practice block with the concept category *animals* (e.g., dog, cat) and the attribute category *good words* as the focal categories and the concept category *trees* (e.g., oak, beech) and the attribute category *bad words* as nonfocal categories (see Table 4 for an overview of the procedure). The first four trials presented only stimuli of the concept categories *animals* and *trees*, and the following 16 trials alternated stimuli of the concept categories and stimuli of the attribute categories. After the practice block, the concept categories *STEM* and *languages* were introduced and the lists of *STEM*- and *languages*-stimuli were shown on the screen. Furthermore, the lists of *good* and *bad* words were shown. Participants completed four test blocks. Following the recommendation of Nosek et al. [68], the attribute category *good* was always focal, and the attribute category *bad* was always nonfocal. Which of the two concept categories of *STEM* and *languages* was focal alternated between test blocks. It was counterbalanced between participants whether they started with the *STEM*-*good*-focal block or with the *languages*-*good*-focal block. The first four trials of each block presented only stimuli of the concept categories and were not analyzed. The following 20 trials of each block alternated stimuli of the concept categories and stimuli of the attribute categories. The order of the stimuli was determined randomly.

Table 4. BIAT procedure [1].

Block Type	N° Test Block	Trials	Nonfocal Categories (Left Key)	Focal Categories (Right Key)
Practice Block		4 trials with concepts only 16 trials alternating concepts and attributes	Tree Bad	Animal Good
Test Block STEM-Good	1	4 trials with concepts only 20 trials alternating concepts and attributes	Languages Bad	STEM Good
Test Block Languages-Good	2	4 trials with concepts only 20 trials alternating concepts and attributes	STEM Bad	Languages Good
Test Block STEM-Good	3	4 trials with concepts only 20 trials alternating concepts and attributes	Languages Bad	STEM Good
Test Block Languages-Good	4	4 trials with concepts only 20 trials alternating concepts and attributes	STEM Bad	Languages Good

[1] The table presents the procedure of the STEM BIAT. The procedure of the Math BIAT was identical. In each BIAT, blocks 1 and 3 are identical, and blocks 2 and 4 are identical. The order of blocks 1 and 3 with blocks 2 and 4 was counterbalanced. From the trials of blocks 1 through 4, only the 20 trials alternating concepts and attributes are analyzed.

During all trials of a block, the focal category labels were shown on the top of the screen (e.g., "STEM or Good"), and the response keys were shown on the bottom of the screen, with the response key for nonfocal stimuli in brackets ("L-key [A-key]"). The response keys were presented as a reminder to reduce potential error variance stemming from careless reading of the instructions. The concept category labels and stimuli were presented in green. The attribute labels and stimuli were presented in yellow. The background color was black. On each trial, a stimulus was shown in the center of the screen until participants responded. In case of an incorrect response, a red "X" appeared below the stimulus until participants gave the correct response. The intertrial interval was 400 ms.

The stimuli of the Math BIAT were taken from previous research using Math IATs [41,42,48]. As our sample was German speaking, we used *German language* as the comparison category (see Table 3). Otherwise, the Math BIAT was identical to the STEM BIAT.

3. Results

3.1. Analyses of the BIATs

We used the scoring algorithm recommended by Nosek et al. [68]. Responses from practice trials and the first four trials of each block were deleted. The dependent variable was the latency from stimulus onset to the correct response. Recall that when participants made an error, they had to correct their response. On these trials, the total latency from stimulus onset to the final correct response was used as dependent variable. Responses with latencies slower than 10,000 ms were deleted. Latencies faster than 400 ms were recoded to 400 ms, and latencies slower than 2000 ms were recoded to 2000 ms. Separate *D* scores were computed for the first two blocks and the second two blocks, and then averaged. To compute the *D* score for the first two blocks of the STEM BIAT, we subtracted the mean response latencies in the STEM-good block from the mean response latencies in the languages-good block, and divided the resulting difference score by the standard deviation of response latencies across both blocks. The *D* score is an individual effect size estimate that is similar to Cohen's *d*. A positive-*D* score indicates a preference for STEM relative to languages, and a negative-*D* score indicates a preference for languages relative to STEM. The Math-BIAT score was calculated in the same vein. A positive-*D* score, thus, indicates a preference for math relative to German, and a negative-*D* score indicates a preference for German relative to math.

3.1.1. BIAT Completion Time

Participants took on average $M = 5.76$ ($SD = 1.68$) minutes to complete the Math BIAT, and $M = 5.89$ ($SD = 1.73$) minutes to complete the STEM BIAT, with no significant difference between BIAT conditions, $t(515) = -0.87$, $p = 0.384$. Older participants took less time than younger participants, as indicated by a significant negative correlation between age and completion time, $r = -0.32$, $p < 0.001$.

3.1.2. BIAT Internal Consistency

As an index of internal consistency, we calculated the Guttman Split-Half coefficient from the *D* scores of the first two and the second two blocks. The internal consistency was excellent for both, the Math BIAT ($\alpha = 0.97$) and the STEM BIAT ($\alpha = 0.95$).

3.1.3. BIAT Construct Validity

To examine the construct validity of the BIATs, we calculated correlations of the *D* scores with explicit attitudes and feeling thermometer scales about math and STEM, respectively. Correlations with self-report measures about German and languages are presented in the Supplementary Materials (Table S1). As expected, we observed a significant positive correlation between implicit math attitudes and explicit math attitudes, $r = 0.14$, $p = 0.020$, as well as between implicit math attitudes and math feelings, $r = 0.16$, $p = 0.011$. Similarly, we observed a significant positive correlation between implicit STEM attitudes and explicit STEM attitudes, $r = 0.17$, $p = 0.005$, as well as between implicit STEM attitudes and STEM feelings, $r = 0.16$, $p = 0.009$.

3.2. Gender Differences in Math- and STEM-Related Measures

We examined gender differences in all math- and STEM-related measures with one-tailed *t*-Tests. Gender differences in German- and languages-related measures are presented in the Supplementary Materials (Table S2). As can be seen in Table 5, we observed the well-known gender differences in almost all math and STEM-related measures. Regarding implicit and explicit attitudes, an interesting pattern emerged. The genders differed in their implicit attitudes about math, with girls showing more negative implicit attitudes about math than boys, $t(260) = 2.68$, $p = 0.004$. However, the genders did not differ in their explicit attitudes about math, $t(515) = 1.52$, $p = 0.064$. Conversely, the genders differed in their explicit attitudes about STEM, with girls showing less positive explicit attitudes about STEM than boys, $t(515) = 2.74$, $p = 0.003$, but not in their implicit attitudes about STEM, $t(253) = 0.98$, $p = 0.165$. When asked about their feelings, participants showed significant gender differences. Girls reported less positive feelings than boys about math, $t(418.7) = 2.87$, $p = 0.002$ (unequal variances assumed) and about STEM, $t(515) = 3.34$, $p < 0.001$.

Table 5. Means, standard deviations, and Cohen's *d* of gender differences in Math- and STEM-related measures.

Measure	Math			STEM		
	Male	Female	Gender Difference	Male	Female	Gender Difference
	***M* (*SD*)**	***M* (*SD*)**	***d***	***M* (*SD*)**	***M* (*SD*)**	***d***
Implicit attitudes	0.07 (0.56)	−0.11 (0.53)	0.34 **	0.02 (0.51)	−0.05 (0.59)	0.13
Explicit attitudes	4.59 (1.37)	4.40 (1.42)	0.14	4.87 (1.14)	4.58 (1.16)	0.25 **
Feeling thermometer	73.81 (25.70)	66.87 (27.88)	0.26 **	69.79 (17.46)	64.14 (19.05)	0.31 ***
Interest	4.66 (1.32)	4.43 (1.40)	0.17 *	4.44 (0.98)	4.20 (1.01)	0.25 **
Aspiration	2.25 (0.97)	2.27 (0.89)	−0.03	2.26 (0.74)	2.24 (0.75)	0.04
Self-concept of ability	4.80 (1.20)	4.27 (1.46)	0.38 ***	4.78 (1.02)	4.20 (1.33)	0.48 ***
Sense of belonging	3.88 (1.44)	3.50 (1.46)	0.26 **	4.17 (1.30)	3.57 (1.35)	0.45 ***

* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$ (one-tailed t-tests).

Furthermore, the genders differed by interest. Girls reported a lower interest in math, $t(515) = 1.83$, $p = 0.034$ and a lower interest in STEM, $t(515) = 2.70$, $p = 0.004$ compared to boys. Interestingly, males and females did not differ in math aspiration, $t(515) = -0.31$, $p = 0.379$ nor in STEM aspiration, $t(515) = 0.38$, $p = 0.351$. The genders did, however, differ in self-concept of abilities. Girls compared to boys reported lower self-concepts of math ability, $t(455.1) = 4.40$, $p < 0.001$ (unequal variances assumed) and lower self-concepts of STEM ability, $t(475.1) = 5.58$, $p < 0.001$ (unequal variances assumed). Finally, the genders differed in sense of belonging. Girls compared to boys reported a lower sense of belonging to the math community, $t(515) = 2.83$, $p = 0.002$ and a lower sense of belonging to the STEM community, $t(515) = 4.95$, $p < 0.001$.

3.3. Predictive Validity of Implicit Attitudes

We examined whether implicit attitudes predicted interest, aspiration, self-concept of ability, and sense of belonging separately for the math and STEM domains. To this end, we first analyzed zero-order correlations (Tables 6 and 7). All math-related self-report measures were highly correlated with one another. Implicit math attitudes were related to all math-related self-report measures except for self-concept of math ability. In a similar vein, all STEM-related self-report measures were highly correlated with one another. Implicit STEM attitudes were related to all STEM-related self-report measures.

To examine the predictive validity of implicit attitudes, we conducted separate linear regression analyses on the various STEM- and math-related outcome variables. In the first step of each regression analyses, we entered the demographic variables gender, grade level, and school profile (dummy coded as STEM profile vs. not) as control variables. In the second step, we entered implicit attitudes as predictors. Dependent variables were STEM- and math-related interest, aspiration, self-concept of ability, and sense of belonging. The results are summarized in Table 8 (math-related regression analyses) and Table 9 (STEM-related regression analyses).

As can be seen in Table 8, a STEM school profile (but not gender and grade level) significantly predicted math interest. Students attending a school with a STEM profile reported higher math interest than other students. Most importantly, implicit math attitudes significantly predicted math interest over and beyond the control variables. Students with more positive implicit math attitudes reported a higher math interest than students with more negative implicit math attitudes.

Table 6. Correlations among Math-related measures [1].

Measure	1	2	3	4	5	6	7
1. Implicit math attitude	-	0.14 *	0.16 *	0.16 *	−0.14 *	0.12	0.16 *
2. Explicit math attitude		-	0.86 ***	0.87 ***	−0.61 ***	0.79 ***	0.80 ***
3. Math feeling thermometer			-	0.80 ***	−0.61 ***	0.79 ***	0.76 ***
4. Math interest				-	−0.63 ***	0.71 ***	0.75 ***
5. Math aspiration [2]					-	−0.59 ***	−0.55 ***
6. Self-concept of math ability						-	0.77 ***
7. Sense of belonging to math community							-

[1] Correlations with implicit attitudes are based on the sample in the Math-BIAT condition (N = 262), correlations among self-report measures are based on the entire sample (N = 517). [2] Math aspiration was measured in terms of aspired grades, ranging from 1 (highest grade) to 6 (lowest grade). * $p < 0.05$. *** $p < 0.001$.

Table 7. Correlations among STEM-related measures [1].

Measure	1	2	3	4	5	6	7
1. Implicit STEM attitude	-	0.17 **	0.16 **	0.21 ***	−0.22 ***	0.22 ***	0.21 ***
2. Explicit STEM attitude		-	0.71 ***	0.79 ***	−0.49 ***	0.73 ***	0.76 ***
3. STEM feeling thermometer			-	0.70 ***	−0.51 ***	0.64 ***	0.63 ***
4. STEM interest				-	−0.48 ***	0.65 ***	0.70 ***
5. STEM aspiration [2]					-	−0.49 ***	−0.44 ***
6. Self-concept of STEM ability						-	0.72 ***
7. Sense of belonging to STEM community							-

[1] Correlations with implicit attitudes are based on the sample in the STEM BIAT condition (N = 255), correlations among self-report measures are based on the entire sample (N = 517). [2] STEM aspiration was measured in terms of aspired grades, ranging from 1 (highest grade) to 6 (lowest grade). ** $p < 0.01$. *** $p < 0.001$.

Furthermore, a STEM school profile (but not gender and grade level) significantly predicted math aspiration. Students attending a school with a STEM profile reported higher math aspirations than other students. Most importantly, implicit math attitudes significantly predicted math aspiration over and beyond the control variables. Students with more positive implicit math attitudes reported higher math aspirations than students with more negative implicit math attitudes.

Furthermore, gender, grade level, and a STEM school profile significantly predicted self-concept of math ability. Boys reported a higher self-concept of math ability than girls. Students at a higher grade level reported a lower self-concept of math ability than students at a lower grade level. Students attending a school with a STEM profile reported a higher self-concept of math ability than other students. However, implicit math attitudes did not predict self-concept of math ability over and beyond the control variables.

Finally, grade level and a STEM school profile (but not gender) significantly predicted sense of belonging to the math community. Students at a higher grade level reported a lower sense of belonging to the math community than students at a lower grade level. Students attending a school with a STEM profile reported a higher sense of belonging to the math community than other students. Most importantly, implicit math attitudes significantly predicted sense of belonging over and beyond the control variables. Students with more positive implicit math attitudes reported a higher sense of belonging to the math community than students with more negative implicit math attitudes.

As can be seen in Table 9, grade level and a STEM school profile (but not gender) significantly predicted STEM interest. Students at a higher grade level reported lower STEM interest than students at a lower grade level. Students attending a school with a STEM profile reported higher STEM interest than other students. Most importantly, implicit STEM attitudes significantly predicted STEM interest over and beyond the control variables. Students with more positive implicit STEM attitudes reported a higher STEM interest than students with more negative implicit STEM attitudes.

Table 8. Regression analyses on math variables [1].

Variable	Model 1			Model 2		
	B **[95% CI]**	***SE B***	**β**	***B*** **[95% CI]**	***SE B***	**β**
Math interest						
Gender [a]	0.16 [−0.17; 0.49]	0.17	0.06	0.10 [−0.23; 0.43]	0.17	0.04
Grade level	<0.01 [−0.08; 0.08]	0.04	<0.01	<0.01 [−0.08; 0.08]	0.04	<0.01
STEM school profile [b]	0.55 ** [0.22; 0.88]	0.17	0.21	0.55 ** [0.22; 0.88]	0.17	0.21
Implicit math attitudes				0.35 * [0.06; 0.64]	0.15	0.14
R^2	0.052 **			0.072 ***		
ΔR^2				0.020 *		
Math aspiration						
Gender [a]	−0.03 [−0.25; 0.20]	0.11	−0.02	0.01 [−0.21; 0.24]	0.11	0.01
Grade level	−0.02 [−0.08; 0.03]	0.03	−0.06	−0.02 [−0.08; 0.03]	0.03	−0.06
STEM school profile [b]	−0.30 ** [−0.52; −0.08]	0.11	−0.17	−0.30 ** [−0.52; −0.08]	0.11	−0.17
Implicit math attitudes				−0.22 * [−0.42; −0.03]	0.10	−0.14
R^2	0.039 *			0.057 **		
ΔR^2				0.018 *		
Self-concept of math ability						
Gender [a]	0.47 ** [0.14; 0.79]	0.16	0.17	0.43 * [0.10; 0.75]	0.17	0.16
Grade level	−0.08 * [−0.15; −0.004]	0.04	−0.13	−0.08 * [−0.16; −0.01]	0.04	−0.13
STEM school profile [b]	0.48 ** [0.16 0.81]	0.16	0.18	0.48 ** [0.16 0.80]	0.16	0.18
Implicit math attitudes				0.22 [−0.07; 0.50]	0.15	0.09
R^2	0.074 ***			0.082 ***		
ΔR^2				0.008		
Sense of belonging to math community						
Gender [a]	0.30 [−0.04; 0.65]	0.18	0.11	0.24 [−0.11; 0.59]	0.18	0.08
Grade level	−0.09 * [−0.17; −0.01]	0.04	−0.14	−0.09 * [−0.17; −0.01]	0.04	−0.14
STEM school profile [b]	0.70 *** [0.35; 1.05]	0.18	0.25	0.70 *** [0.35; 1.04]	0.18	0.25
Implicit math attitudes				0.36 * [0.05; 0.66]	0.16	0.14
R^2	0.079 ***			0.097 ***		
ΔR^2				0.019 *		

[1] In Model 1, we entered the control variables gender, grade level, and STEM school profile to predict the outcome variables. In Model 2, we entered implicit math attitudes as predictor. [a] 0 = female, 1 = male. [b] 0 = no STEM profile, 1 = STEM profile. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

Table 9. Regression analyses on STEM variables [1].

Variable	Model 1			Model 2		
	B **[95% CI]**	***SE B***	**β**	***B*** **[95% CI]**	***SE B***	**β**
STEM interest						
Gender [a]	0.14 [−0.13; 0.40]	0.14	0.06	0.12 [−0.15; 0.38]	0.13	0.05
Grade level	−0.12 *** [−0.18; −0.06]	0.03	−0.25	−0.12 *** [−0.18; −0.06]	0.03	−0.25
STEM school profile [b]	0.41 ** [0.16; 0.67]	0.13	0.20	0.37 ** [0.12; 0.62]	0.13	0.18
Implicit STEM attitudes				0.36 ** [0.15; 0.58]	0.11	0.20
R^2	0.088 ***			0.126 ***		
ΔR^2				0.038 **		
STEM aspiration						
Gender [a]	0.11 [−0.09; 0.32]	0.10	0.07	0.13 [−0.07; 0.33]	0.10	0.08
Grade level	−0.02 [−0.06; 0.03]	0.02	−0.05	−0.02 [−0.06; 0.03]	0.02	−0.05
STEM school profile [b]	−0.2 ** [−0.44; −0.05]	0.10	−0.16	−0.21 * [−0.41; −0.02]	0.10	−0.14
Implicit STEM attitudes				−0.29 *** [−0.46; −0.13]	0.09	−0.21
R^2	0.030			0.075 ***		
ΔR^2				0.045 ***		
Self-concept of STEM ability						
Gender [a]	0.48 ** [0.14; 0.82]	0.17	0.17	0.46 ** [0.12; 0.79]	0.17	0.16
Grade level	−0.05 [−0.12; 0.03]	0.04	−0.07	−0.05 [−0.12; 0.03]	0.04	−0.07
STEM school profile [b]	0.53 ** [0.20; 0.85]	0.17	0.20	0.47 ** [0.15; 0.80]	0.16	0.18
Implicit STEM attitudes				0.46 ** [0.18; 0.74]	0.14	0.19
R^2	0.078 ***			0.115 ***		
ΔR^2				0.037 **		
Sense of belonging to STEM community						
Gender [a]	0.52 ** [0.17; 0.87]	0.18	0.18	0.49 ** [0.15; 0.84]	0.18	0.17
Grade level	−0.09 * [−0.16; −0.01]	0.04	−0.13	−0.09 * [−0.16; −0.01]	0.04	−0.13
STEM school profile [b]	0.72 *** [0.38; 1.05]	0.17	.26	0.67 *** [0.33; 1.00]	0.17	0.24
Implicit STEM attitudes				0.44 ** [0.15; 0.72]	0.15	0.18
R^2	.114 ***			0.145 ***		
ΔR^2				0.031 **		

[1] In Model 1, we entered the control variables gender, grade level, and STEM school profile to predict the outcome variables. In Model 2, we entered implicit STEM attitudes as predictor. [a] 0 = female, 1 = male. [b] 0 = no STEM profile, 1 = STEM profile. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

Furthermore, a STEM school profile (but not gender and grade level) significantly predicted STEM aspiration. Students attending a school with a STEM profile reported higher STEM aspirations than other students. Most importantly, implicit STEM attitudes significantly predicted STEM aspiration over and beyond the control variables. Students with more positive implicit STEM attitudes reported higher STEM aspirations than students with more negative implicit STEM attitudes.

Furthermore, gender and a STEM school profile (but not grade level) significantly predicted self-concept of STEM ability. Boys reported a higher self-concept of STEM ability than girls. Students attending a school with a STEM profile reported a higher self-concept of STEM ability than other students. Most importantly, implicit STEM attitudes significantly predicted self-concept of STEM ability over and beyond the control variables. Students with more positive implicit STEM attitudes reported a higher self-concept of STEM ability than students with more negative implicit STEM attitudes.

Finally, gender, grade level, and a STEM school profile significantly predicted sense of belonging to the STEM community. Boys reported a higher sense of belonging to the STEM community than girls. Students at a higher grade level reported a lower sense of belonging to the STEM community than students at a lower grade level. Students attending a school with a STEM profile reported a higher sense of belonging to the STEM community than other students. Most importantly, implicit STEM attitudes significantly predicted sense of belonging over and beyond the control variables. Students with more positive implicit STEM attitudes reported a higher sense of belonging to the STEM community than students with more negative implicit STEM attitudes.

4. Discussion

The goals of the present study were twofold. First, we sought to evaluate the reliability and validity of our novel implicit attitude measures in a sample of adolescents participating online on a voluntary basis, at a location and time of their own choice. Second, we sought to provide first evidence on implicit STEM attitudes in adolescents and extend our knowledge on implicit math attitudes and how they relate to other STEM and math cognitions.

Regarding our first goal, the present study confirms the reliability and validity of both the Math BIAT and the STEM BIAT in our adolescent sample under the conditions of self-determined online participation. The internal consistency of both BIATs was excellent and slightly better than the internal consistencies of the BIAT and the IAT reported in previous research [58,68]. Criterion validity was evaluated based on correlations with self-report measures of attitudes. To this end, we administered explicit attitude scales consisting of three items as well as feeling thermometer items regarding the school subjects [48]. As implicit and self-report measures are thought to assess distinct, but related constructs [59], we expected small-to-medium-sized correlations. Similar to previous research on implicit–explicit math attitude correlations in underaged participants [52], we observed small-sized correlations of implicit and explicit math attitudes as well as of implicit and explicit STEM attitudes. This pattern of results was confirmed across both self-report measures, the explicit attitude scale and the feeling thermometer items, with the latter tapping into the affective component of attitudes. Taken together, the present study provides evidence that implicit attitudes about math and STEM can be measured reliably and validly in adolescents using our adaptation of the BIAT. As such, the BIAT constitutes a useful alternative to the standard IAT, possessing several advantages (shorter completion time and less cognitively taxing than the standard IAT), without compromising reliability and validity.

Regarding our second goal, the present study reveals several interesting results. We replicate previous findings that females have more negative implicit attitudes about math than males [41,52]. At the same time, the genders did not differ in their explicit attitudes about math. This pattern underscores the added value of implicit measures when investigating attitudes about math. Interestingly, we did not observe gender differences in implicit attitudes about STEM. This is particularly noteworthy because we observed gender differences in explicit attitudes about STEM, with boys reporting more positive attitudes and more positive feelings about STEM. At present, it is difficult to conclusively interpret the observed pattern of gender differences. It is important to note that we did not draw a representative sample and, therefore, our results on gender differences must be interpreted with caution. Our self-selected sample may likely be biased toward STEM-interested adolescents because we advertised the study as a study on STEM. Consequently, the observed gender difference may underestimate the actual gender differences in the population.

Most importantly, our results show that both implicit attitudes about math and implicit attitudes about STEM predicted a variety of other math- and STEM-related cognitions, respectively. In particular, implicit attitudes about math as well as implicit attitudes about STEM predicted interest in and aspiration for math and STEM, respectively. Furthermore, implicit STEM (but not math) attitudes predicted self-concept of ability. Finally, implicit attitudes about math as well as implicit attitudes about STEM predicted sense of belonging to the math and STEM communities, respectively. These findings are noteworthy, because they demonstrate that implicit attitudes contribute to several motivational factors, such as interest, aspiration, and self-concept of ability, which eventually play a role in career decisions. Moreover, the nearly parallel pattern of relations of implicit math attitudes and self-reported math cognitions on one side and implicit STEM attitudes and self-reported STEM cognitions on the other side confirms the generality of the findings. Finally, this is, to our knowledge, the first evidence showing that implicit attitudes predict sense of belonging to the respective community. Sense of belonging has recently been identified as one major factor contributing to gender gaps in STEM participation [6]. Our findings add to this literature by showing that implicit attitudes are related to a sense of belonging with respect to both math and STEM.

Furthermore, the present research points to the idea that intervention programs aiming at increasing female participation rates in STEM should focus not only on changing explicit cognitions but also on changing implicit cognitions [73–75]. Decades of social-psychological research on the change of implicit attitudes demonstrate that implicit attitudes can be changed in the short term by a variety of interventions [76]. However, long-term change is difficult to maintain [77]. At the same time, implicit attitudes play an important role in behavior, decision-making, and motivation [31]. Thus, it is essential to investigate how long-term change of implicit attitudes about STEM can be achieved. Instilling and maintaining positive association with STEM in girls may constitute one route to eventually increasing the rate of females entering and staying in STEM.

In interpreting our findings, it must be kept in mind that one characteristic of IAT measures is that they are inherently relative in nature. That is, they measure associations with one category relative to a contrast category. When drawing conclusions from IAT findings, one must therefore keep in mind that the choice of the contrast category contributes to the final IAT score. In our case, we selected German as the contrast category for the Math BIAT and languages as the contrast category for the STEM BIAT. Participants' national language has been the standard contrast category in Math IATs [41,52]. This choice is based on the fact that the national language and math are school subjects students typically take from first grade on. Moreover, gender stereotypes with respect to math and reading develop early in childhood [45]. Thus, the national language is an obvious contrast category to math.

Our novel STEM BIAT was modeled after science IATs that contrast science with liberal arts or humanities [12]. While the concepts of liberal arts or humanities are known to university students, school students are not yet familiar with these concepts. Therefore, we chose languages as the contrast category. The category of languages is easy to understand, and it is obvious which exemplar stimuli belong to this category. Furthermore, the category of languages appears to be an appropriate contrast category to STEM because the higher-track secondary schools in Germany typically offer a STEM or a language profile. Therefore, school students need to reflect on their preferences, interests, and abilities regarding STEM and languages to make an informed decision about which profile they want to choose. While we and many other researchers investigated STEM as a unitary concept, it is also worthwhile to differentiate between STEM subjects that are more or less gender balanced [78]. Whereas physics and computer science still have a low proportion of women, biology and chemistry have achieved almost equal representation of genders, at least among university students [2]. Research has discussed several factors contributing to the different gender distributions in the various STEM subjects, including stereotypes about the particular subjects [47,61,64,79,80]. Thus, future research may disentangle implicit attitudes about the STEM subfields that are more or less gender-balanced [81]. Nevertheless, measuring implicit attitudes about STEM as a unitary concept is a useful and important endeavor because STEM is presented as a unitary concept in education systems, and many secondary schools offer a STEM or a language profile (among other profiles), which requires students to reflect on their STEM interests and abilities.

5. Conclusions

In sum, the present research demonstrates for the first time that implicit attitudes about math and STEM can be measured reliably and validly in an online sample of adolescents. As such, our online BIATs provide efficient measurement tools for future research. Our findings demonstrate that implicit attitudes are related to motivational and social-psychological factors (interest, aspiration, self-concept of abilities, and sense of belonging), which are known factors contributing to gender gaps in STEM participation. Thus, our findings underscore the significance of implicit attitudes in the STEM domain.

Future research may further investigate the role of implicit attitudes in behavior, decision making, and emotional experiences. Dual-process models [34,35] and models of implicit cognition [31–33] provide a solid theoretical basis on which several predictions can be derived. For instance, it would be interesting to examine the predictive validity of implicit attitudes with respect to classroom behavior such as asking questions or approaching the teacher after class [73]. Furthermore, it would be interesting to investigate the predictive validity of implicit attitudes with respect to future career decisions such as entering or dropping out of the STEM domain. Also, it would be interesting to investigate the relation of implicit attitudes to well-being and stress experiences when working on STEM tasks. Taken together, implicit attitudes may play a significant role in a variety of STEM-related variables.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/educsci13090899/s1, Table S1: Correlations among German- and languages-related measures; Table S2: Means, standard deviations, and Cohen's *d* of gender differences in German- and languages-related measures.

Author Contributions: Conceptualization, R.R., K.J.E. and S.S.; methodology, R.R., C.R. and L.R.; software, R.R., C.R. and L.R.; formal analysis, R.R.; investigation, C.R. and L.R.; data curation, R.R.; writing—original draft preparation, R.R.; writing—review and editing, R.R., C.R., L.R., K.J.E. and S.S.; supervision, R.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of the University of Regensburg (protocol code 21-5659-101, date of approval 17 January 2021).

Informed Consent Statement: Informed consent was obtained from all subjects and their parents involved in the study.

Data Availability Statement: The data presented in this study are openly available at https://osf.io/9sz32 (accessed on 26 May 2023).

Acknowledgments: We are thankful to all who distributed the link to the study.

Conflicts of Interest: The authors declare no conflict of interest.

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