5

Online Mentoring for Talented Girls in STEM: The Role of Relationship Quality and Changes in Learning Environments in Explaining Mentoring Success

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Abstract

Although participation rates of women in science, technology, engineering, and mathematics (STEM) are continually improving, low rates are still an issue in many countries. While previous studies found positive effects of online mentoring for increasing girls' interests in STEM, research concerning explanatory mechanisms is lacking. We found evidence that in a 1-year online mentoring program for girls (age: M = 13.82 years, N = 998) in STEM, suitably implemented mentoring (operationalized via relationship quality in a program that systematically incorporates structural and organizational aspects of successful mentoring) was associated with positive changes in the learning environments of the mentees (as indicated by their increasing educational capital). These positive changes were associated with increases in the program-related mentoring outcomes STEM activities and elective intentions in STEM. Finally, we found that suitably implemented online mentoring was indirectly related to an increase in these two mentoring outcomes via an increase in educational capital. These results indicate the importance of paying close attention to learning environments when planning interventions. © 2019 The Authors. New Directions for Child and Adolescent Development *published by Wiley Periodicals, Inc.*

The low participation rates of girls and women in science, technology, engineering, and mathematics (STEM) remain a critical issue for social scientists, educationalists, business associations, and politicians. Although international comparative studies of educational achievement indicate that girls in many countries now achieve on par with or even outperform boys in mathematics and the natural sciences (Stoet & Geary, 2018), women remain underrepresented in many degree programs and occupations in STEM. Numerous studies have explored the reasons behind these different participation rates (Kelly, 2016; Wang, 2013; Wang & Degol, 2013). The studies indicate that besides factors at the individual level (e.g., interest, confidence in one's own STEM abilities, or motivational beliefs), factors at the environmental level (e.g., stereotypes about gender and STEM, parental beliefs and behavior, lack of suitable female role models) also contribute to the low participation rates of females. Measures undertaken to redress the situation should therefore focus on both causal bundles as well as their interplay. Moreover, such interventions need to start early enough, as gender differences in individual factors become larger with age. For example, girls' interest in STEM decreases more than that of boys as they progress through school (Frenzel, Goetz, Pekrun, & Watt, 2010).

Mentoring can take all these issues into consideration and can therefore be a particularly promising means of promoting girls in STEM. Various studies support this assumption (e.g., Stoeger et al., 2016). However, research concerning explanatory mechanisms is still lacking. Therefore, the current study focuses on these mechanisms. Within the setting of a 1-year online mentoring program for girls interested in STEM, the study examines whether suitably implemented mentoring (operationalized via relationship quality, in a program that assures the structural and organizational aspects for successful mentoring) is associated with changes in the learning environments of the mentees (as indicated by their increasing educational capital) and whether these changes in turn are related to positive developments of the outcome variables.

In the following theoretical section, we will first briefly explain why mentoring—and especially online mentoring—is a promising way to support girls in STEM. We will then introduce the educational capital approach that we use to assess the STEM-related learning environments of our mentees. After explaining a rationale for using relationship quality as one possible operationalization for successfully implemented online mentoring, we will describe the setting in which we conducted our study, the online mentoring program CyberMentor.

Online Mentoring as a Promising Way to Increase STEM Participation of Girls

Correctly implemented, mentoring addresses both individual and environmental causes of girls' low STEM participation rates. Women who study a

STEM subject or work in a STEM field are particularly suitable as mentors in STEM-focused mentoring. They can act as role models and thus positively influence girls' interest, self-confidence, and elective intentions through conversations and other STEM-knowledge-building mentee–mentor activities (Dasgupta, 2011).

However, women's low participation rates in STEM make finding suitable female mentors in the immediate vicinity of the female mentees difficult. This circumstance is exacerbated by the often very full schedules of women working in STEM professions. Such women are often very busy during the afternoon, while younger mentees typically only can meet with mentors during the daytime. Appropriate mentor–mentee matching and sufficiently frequent mentor–mentee interactions are crucial prerequisites for successful mentoring in STEM (Stoeger & Ziegler, 2012). Yet both are difficult to realize in an offline setting. It is difficult to find a sufficient number of suitably qualified women working in STEM who live near mentees and have sufficient time for meetings in person during the daytime. Online mentoring offers solutions to both problems. It is not dependent on participants' physical proximity and does not require synchronous meetings in person.

Previous studies bear out the effectiveness of online mentoring for promoting talented girls in STEM in particular on account of its mobility and greater scheduling flexibility. Stoeger and colleagues (Stoeger et al., 2016; Stoeger, Duan, Schirner, Greindl, & Ziegler, 2013) showed that STEM activities, certainty about career plans, and the intention to study a STEM subject developed more positively among talented girls who had taken part in a 1-year online mentoring program than among pupils in a waitlist control group. The waitlist control group consisted of comparably talented and interested girls who had also registered for the program but were only allowed to take part 1 year later. Including a randomized waitlist control group in the study design allowed positive changes on the aforementioned variables to be attributed to the mentoring the girls had received and not to the remarkable characteristics that the girls who chose to enroll in the program shared with one another prior to program participation. This empirical clarification is particularly important, because talented girls who sign up for mentoring programs in STEM differ from their peers who do not. In the latter study by Stoeger et al. (2016), for example, the pupils in the mentoring and the waitlist control groups both showed significantly more positive characteristics (e.g., grades, aspirations, interest in STEM, self-confidence) than the pupils in a randomly selected comparison group who had not registered for the program. Intriguingly, however, the researchers did not find any more favorable characteristics with regard to the learning environment of the female pupils who had registered for the online mentoring program.

The results reported above show that online mentoring can be an effective means of promoting talented girls in STEM. However, little is known about the exact mechanisms responsible for such efficacious outcomes. The

aim of our study is therefore to take a closer look at the mediating mechanisms of a STEM mentoring program for girls for which treatment effectiveness has already been established. Findings on unfavorable environmental conditions for talented girls in STEM (Ceci, Williams, & Barnett, 2009; van den Hurk, Meelissen, & van Langen, 2019) suggest that the documented beneficial effects of mentoring for girls' in STEM may be resulting from positive changes that are taking place in girls' learning environments. This should also apply for girls who are showing positive individual characteristics such as high interest and outstanding performance in STEM. To the best of our knowledge, no studies to date have investigated this assumption. We therefore investigated whether suitably implemented mentoring is related to positive changes in girls' learning environments. We also examined whether and to what extent any expected positive changes in the girls' learning environments—were we to observe such positive changes—were associated with positive changes in the mentoring outcomes (i.e., STEM activities, elective intentions in STEM, and certainty about career plans). To systematically consider the mentees' learning environments, we applied the educational capital approach as introduced by Ziegler and Baker in the field of talent development (Ziegler & Baker, 2013).

The Learning Environment of Talented Girls in STEM: A Categorization Based on the Educational Capital Approach

Numerous theoretical models and empirical studies have shown various environmental factors to be important for explaining different participation rates in STEM (e.g., Ceci et al., 2009; van den Hurk et al., 2019). However, these findings do not reflect a shared theoretical framework. They are often discussed piecemeal or categorized simply in terms of the settings to which they can be assigned (e.g., school, home). The educational capital approach used in talent-development research does provide a unified theoretical framework, on the other hand, by exhaustively categorizing the resources in the environment of learners in terms of their influence on learning and educational processes (Ziegler & Baker, 2013). The approach distinguishes five types of *educational capital*—namely economic, cultural, social, infrastructural, and didactic educational capital—that can influence learning and educational processes in different ways. We briefly introduce the five types of educational capital and report studies in which gender differences in the availability or use of the different types of educational capital (or related variables) have been demonstrated. Importantly, these findings showed that boys' and girls' respective environments were differentially beneficial for their learning in STEM.

Applied to the STEM field, *economic educational capital* refers to any kind of assets, possessions, money, or valuables that can be used to initiate and maintain educational and learning processes in STEM. In contrast to the other types of educational capital, the influence of economic educational

capital is indirect. For example, it can be used to purchase learning materials (e.g., STEM books or an experimental kit). Research indicates that parents invest less economic capital in STEM promotion for girls than for boys (e.g., Bussey & Bandura, 1999; Downey & Vogt Yuan, 2005).

Cultural educational capital includes values, thinking patterns, and attitudes that may facilitate or hinder the achievement of learning and educational goals in STEM. A typical example of advantageous cultural educational capital is parents who value learning and education. The more positive these attitudes are, the better pupils perform (Fuligni, 1997). In light of these findings, results of studies (Moesko, 2010; Robnett, 2016) showing that parents and teachers consider girls less suitable for STEM than boys— even when girls and boys are achieving in STEM at equal levels—seem to be especially problematic. Entrenched stereotypes about STEM as a male domain thus represent negative cultural educational capital for girls (e.g., Cvencek, Meltzoff, & Greenwald, 2011).

Social educational capital comprises all persons and societal institutions that can directly or indirectly influence the success of learning and educational processes in STEM. Studies indicate that girls have less social educational capital in STEM at their disposal than boys. For example, girls report having fewer discussion partners on STEM topics and fewer mentors in STEM fields (Stoeger et al., 2012).

Infrastructural educational capital comprises all materially implemented options for action that enable or promote learning and education in STEM. Infrastructural educational capital for promoting development in STEM is less favorable for girls (e.g., Bussey & Bandura, 1999; Lengfelder & Heller, 2002; Stoeger, Greindl, Kuhlmann, & Balestrini, 2017). This holds both for action options that indirectly facilitate learning in STEM (e.g., toys or leisure activities related to STEM) and for action options that facilitate institutional learning (e.g., attending STEM schools or participating in extracurricular programs in STEM).

Didactic educational capital refers to the accumulated know-how for designing and improving educational and learning processes in STEM. Indications are that girls have less didactic capital in STEM. Girls use extracurricular STEM offerings less frequently than boys (Lengfelder & Heller, 2002; Stoeger et al., 2017). During STEM instruction, teachers call on girls less often and afford them less time to come up with correct answers (Schirner, 2013).

In light of such findings, it appears clear that girls' educational capital in STEM is less favorable than that of boys. Even girls with above-average levels of interest in STEM and self-reported individual characteristics that were comparable to those reported by boys nevertheless reported having learning environments that were less auspicious for development in STEM (Stoeger et al., 2016). In light of the findings summarized here, the question arises as to whether suitably implemented mentoring can positively influence girls' educational capital and thereby improve the capacity of their

environments for STEM learning. Before we explore this question, a brief explanation of relationship quality as a possible operationalization of "suitably implemented" mentoring is necessary.

The Quality of Relationships as a Characteristic of Successfully Implemented (Online) Mentoring

Meta-analyses have shown that mentoring is only effective under certain conditions (e.g., DuBois, Holloway, Valentine, & Cooper, 2002; DuBois, Portillo, Rhodes, Silverthorn, & Valentine, 2011; Eby et al., 2013; Eby, Allen, Evans, Ng, & DuBois, 2008). Structural and organizational aspects such as sufficient duration of mentoring, regular exchanges between mentee and mentor, or supervision and training of mentors are important prerequisites of effective mentoring. If these structural and organizational aspects are fulfilled, the quality of the relationship between mentor and mentee is a meaningful indicator of successfully implemented mentoring (Bayer, Grossman, & DuBois, 2015; Goldner & Mayseless, 2009; Nakkula & Harris, 2005; Parra, DuBois, Neville, Pugh-Lilly, & Povinelli, 2002; Rhodes, Spencer, Keller, Liang, & Noam, 2006). For example, Holmes, Redmond, Thomas, and High (2012) were able to show that in a 1-year afterschool mentoring program for female middle school students supervised by female engineering students, the quality of the relationship correlated with the mentoring outcome of confidence in one's own mathematics ability. In a study by Xu and Payne (2014), the quality of the mentoring relationship predicted outcomes such as job satisfaction or commitment.

The quality of relationships also plays an important role in online mentoring programs, but establishing closer relationships online appears more difficult due to the computer-based communication and the lack of personal contacts (Rhodes, Spencer, Saito, & Sipe, 2006). In order to investigate whether successfully implemented online mentoring positively changes mentees' educational capital—and thus their learning environments—in STEM, it must first be ensured that the online mentoring program under consideration fulfills relevant structural and organizational characteristics (DuBois et al., 2002; DuBois et al., 2011; Eby et al., 2008; Eby et al., 2013). However, even when the program under examination offers the right structural and organizational characteristics, it can be assumed—in light of the literature on mentoring relationships we introduced above—that positive changes in educational capital are contingent on a good mentee–mentor relationship. We therefore conducted our study in an online mentoring program that planned its structural and organizational characteristics according to existing findings on effective mentoring. The meta-analytical mentoring literature informed the program's design and implementation with respect to factors such as the overall duration and frequency of mentee–mentor interactions. Research on girls in STEM informed the program's

matching of mentors and mentees. Women working in STEM professions were matched with girls based on the similarity of both STEM interests and hobbies. We first describe this mentoring program before we present the research questions of our study.

CyberMentor: An Online Mentoring Program for Talented Girls in STEM

CyberMentor is a Germany-wide online mentoring program. Mentees are students between the ages of 11 and 18. Each mentee is supervised by a personal mentor for at least 1 year. Mentors are women who have at least a bachelor's degree in a STEM field and are working on graduate degrees in a STEM field, doing postdoctoral research, or are working professionally in STEM. Mentee–mentor interaction takes place on a members-only online platform via an internal email system, chat, and forums. Mentees and mentors agree to exchange information with one another for at least half an hour each week for at least 1 year. In addition to mentee–mentor interaction, the platform also enables networking with up to 1,600 other program participants. The mentoring is free of charge for the students. The mentors are volunteers.

The program duration of 1 year, the minimum weekly mentee–mentor interaction time of 30 minutes, online training courses for mentors, and supervision by the project team ensure that important structural and organizational aspects of successful mentoring are fulfilled. The matching of mentors and mentees on the basis of STEM interests and hobbies should contribute to a good mentee–mentor fit and to the quality of their relationships. Nevertheless, it can be assumed that relationship quality varies between the mentoring pairs.

Current Study

As the explanations above show, on the one hand, the learning environments of girls in STEM differ unfavorably from those of boys. On the other hand, there are clear differences in various individual characteristics (e.g., interest, confidence in one's own abilities, see Stoeger et al., 2016). These findings raise the question of the most promising approaches for improving the situation of girls in STEM.

Research Question 1. Previous studies have often focused on individual characteristics or on interventions that tried to positively influence individual characteristics of girls in STEM (e.g., interest, confidence in one's own abilities). We looked instead into the question of whether suitably implemented online mentoring is positively related to the STEM-development-relevant environments of talented female students. We operationalized suitably implemented mentoring with the help of the relationship quality between mentor and mentee. Suitably implemented

mentoring also meant that the program we were studying attended to known program-inherent structural and organizational features of successful mentoring. We therefore arrived at our first research question: Is suitably implemented online mentoring (operationalized via relationship quality) related to an increase of STEM-specific educational capital in talented female students?

Research Question 2. We assume that for female students already interested in STEM and talented in this area, positive changes in the learning environment would be accompanied by positive changes in mentoring outcomes that have been shown to be related to later real-life choices in STEM. Such outcomes include STEM activities, elective intentions in STEM, and certainty about career plans (Dasgupta & Stout, 2014). Hence, we arrived at our second research question: Is a positive change in STEM-specific educational capital associated with an increase in STEM activities, elective intentions in STEM, and certainty about career plans?

Research Question 3. If the answers to the first two research questions are affirmative, it seems important to then also take a closer look at the interplay among the analyzed mechanisms of action. In a final step, we therefore also considered the interplay among relationship quality, changes in educational capital, and changes in mentoring outcomes to better understand the mechanisms of effective online mentoring for talented girls in STEM. These considerations yielded our third and final research question: Is suitably implemented online mentoring (operationalized via relationship quality) indirectly related to an increase in STEM activities, elective intentions in STEM, and certainty about career plans via an increase in educational capital?

Method

Sample and Procedure. For our longitudinal mediation analyses using the parallel process latent growth curve approach (Cheong, MacKinnon, & Khoo, 2003; see section Data Analysis), a large sample size was required to ensure appropriate power. A simulation study of Cheong (2011) estimated that for statistical power of .80 or higher—and assuming medium effect sizes and three measurement occasions—approximately 1,000 participants are necessary.

For our study, we combined data from three mentoring years (2013–2014, 2014–2015, and 2015–2016). 1,258 female students (age: $M = 13.82$ years, $SD = 2.09$) enrolled in high achiever track secondary education from throughout Germany took part in the online mentoring program Cyber-Mentor as first-time program participants. All participating students were asked to fill out an online questionnaire at three points in time over the course of 1 year. The first time point was before the beginning of the mentoring year, the second time point was after the first half of the mentoring year, and the third time point was at the end of the mentoring year.

Our final sample included the data of 998 mentees who filled out the questionnaires at least at one of the three time points. 954 mentees (95.6%) filled out the questionnaire at time point 1; 412 mentees (41.3%) did so at time point 2; and 210 mentees (21.0%) did so at time point 3. Missing data were handled using the full information maximum likelihood method, which is also appropriate for longitudinal studies with substantial attrition as in our study (Graham, 2009). As our latent growth curve models included the same outcome variables at different time points, no further auxiliary variables should be needed, as previous measures of the same variable are hard to surpass concerning predictive strength of later measures (Graham, 2009).

Measures.

Educational Capital in STEM. We assessed educational capital in STEM with the Questionnaire of Educational and Learning Capital (QELC; Vladut, Liu, Leana-Tascilar, Vialle, & Ziegler, 2013), which was adapted to the domain of STEM. The adapted scale showed predictive validity with respect to females' later STEM behaviors in other studies (Ziegler, Debatin, & Stoeger, 2019). We used the five subscales for measuring economic, cultural, social, infrastructural, and didactic educational capital. Each subscale consists of five items. Respondents estimated the extent of their respective educational capital on a six-point Likert-type scale ranging from 1 (*completely disagree*) to 6 (*completely agree*). A sample item for cultural educational capital reads: "In my social environment, learning for STEM subjects is considered to be very important." We calculated a mean score out of the five subscales to obtain the overall measure for educational capital. Cronbach's alpha was .93, .93, and .94 for the three time points.

Certainty About Career Plans. We assessed participants' certainty about career plans with a ten-item scale (Seifert & Stangl, 1986). Respondents indicated how certain they were about their future career plans on a six-point Likert-type scale ranging from 1 (*completely disagree*) to 6 (*completely agree*). All items were worded without particular reference to the STEM domain. A sample item reads: "I know quite well for which careers I am best suited." Cronbach's alpha was .91, .91, and .91 for the three time points.

Elective Intentions in STEM. We assessed participants' elective intentions in STEM with a five-item scale (Stoeger et al., 2013). Respondents indicated on a six-point Likert-type scale ranging from 1 (*completely disagree*) to 6 (*completely agree*) how well they could picture themselves choosing a university major in STEM, choosing a STEM subject for a track or course at school or in college, or pursuing a career in a STEM field. A sample item reads: "I can picture myself majoring in a STEM subject." Cronbach's alpha was .82, .85, and .88 for the three time points.

STEM Activities. We assessed participants' levels of STEM activities with a nine-item scale (Stoeger et al., 2016). Respondents indicated on a six-point Likert-type scale how often they were typically engaged in different

STEM activities. The endpoints are formulated as statements, for example: "I have never read a book about STEM before." versus "I have read books about STEM very often." Cronbach's alpha was .81, .80, and .82 for the three time points.

Relationship Quality. We assessed study participants' perceived relationship quality with their respective mentoring partner with a six-item scale at the third time point, at the end of the mentoring year. The scale is an adapted and shortened German version of the relational quality scale from the Youth Mentoring Survey (Harris & Nakkula, 2008). Respondents evaluated the quality of the relationship with their personal mentoring partner on a six-point Likert-type scale ranging from 1 (*completely disagree*) to 6 (*completely agree*). Sample items read: "I got along very well with my mentor." and "I also talked to my mentor about personal matters." Cronbach's alpha was .85.

Data Analysis. Our analyses are based on the latent growth curve approach. In the latent growth curve approach—which is situated in the framework of structural equation modeling (Bollen & Curran, 2006)—a growth process of a variable repeatedly assessed at consecutive time points is modeled by two latent variables, the intercept factor and the slope factor. The intercept factor represents the initial level of the variable of interest while the slope factor represents the change of this variable over the assessed time points. Variances of these factors represent individual differences in initial level and in the amount of change, respectively. In extended growth models the two factors can be regressed on other variables or several growth processes can be modeled simultaneously (i.e., parallel process latent growth curve models) to investigate relationships with the individual growth trajectories. In the following, we describe the models we used to test our research questions.

Models Used for Answering Our Research Questions.

Research Question 1. *Is suitably implemented online mentoring (operationalized via relationship quality) related to an increase of STEM-specific educational capital in talented female students?* For Research Question 1, we first calculated an unconditional latent growth curve model (i.e., a model without covariates) using only the three consecutive measurements of educational capital to evaluate its growth process over the course of the program. In a second step we regressed the slope factor on relationship quality to test the association between relationship quality and the development of educational capital (i.e., with a conditional growth model).

Research Question 2. *Is a positive change in STEM-specific educational capital associated with an increase in STEM activities, elective intentions in STEM, and certainty about career plans?* For Research Question 2, we first calculated the unconditional growth model of each outcome variable separately to evaluate its growth process over the course of the program. We then estimated three parallel process latent growth curve models (growth of the outcomes and growth of educational capital modeled simultaneously),

Table 5.1. Descriptive Statistics

	M			SD			
	T_1	T_2	T_3	T_1	T_2	T_3	Range
Educational capital	3.72	3.72	3.72	0.75	0.82	0.85	1–6
Certainty about career plans	3.59	3.69	3.70	1.10	1.10	1.12	1–6
Elective intentions in STEM	4.76	4.81	4.79	0.84	0.85	1.03	1–6
STEM activities	3.78	3.99	4.13	0.95	0.89	0.89	1–6
Relationship quality	–	–	4.07	–	–	1.12	1–6

Note. N varies between 185 and 954 depending on time point and variable.

thereby assessing the correlations between the slope factor of educational capital and the slope factors of each of the three outcome variables.

Research Question 3. Is suitably implemented online mentoring (operationalized via relationship quality) indirectly related to an increase in STEM activities, elective intentions in STEM, and certainty about career plans via an increase in educational capital? For Research Question 3, we calculated three longitudinal slope-only mediation models that combined the models of Research Questions 1 and 2 by regressing the slope of each outcome on the slope of educational capital and on relationship quality, while the slope of educational capital was also regressed on relationship quality (Cheong et al., 2003; von Soest & Hagtvet, 2011).

The growth curves of all variables were based on the mean scores of the scales at the three time points. In all of the growth curve models, we specified growth trajectories to be linear.

Estimation of the Models. The analyses were conducted with M*plus* 6 (Muthén & Muthén, 1998–2010). The maximum-likelihood (ML) estimator was used for all analyses. Model fit was assessed following the criteria of Hu and Bentler (1999). Therefore, a value close to .95 for the Comparative Fit Index (CFI), a value close to .06 for the root mean squared error of approximation (RMSEA), and a value close to .08 for the standardized root mean squared residual (SRMR) were the cutoff criteria for assuming good model fit.

Results

Descriptive Statistics. Descriptive statistics of all scales at the three time points are provided in Table 5.1. The correlations are provided in Table 5.2.

Growth Curve Models. All of the linear growth curve models we used to answer our research questions showed very good model fit according to every index we examined (see Table 5.3).

Research Question 1. Is suitably implemented online mentoring (operationalized via relationship quality) related to an increase of STEM-specific

Table 5.2. Correlations of All Variables (Pairwise)

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. RQ	–											
2. EC1	.12	–										
3. EC2	.13	.63**	–									
4. EC3	.26**	.59**	.71**	–								
5. Act 1	.13	.36**	.28**	.24**	–							
6. Act 2	.13	.33**	.42**	.32**	.58**	–						
7. Act 3	.19*	.28**	.39**	.35**	.66**	.79**	–					
8. EI 1	.08	.20**	.17**	.12	.50**	.37**	.30**	–				
9. EI 2	.12	.03	.18**	.15*	.41**	.44**	.35**	.69**	–			
10. EI 3	.12	.06	.11	.16*	.46**	.43**	.39**	.63**	.77**	–		
11. CCP 1	.03	.17*	.11*	.04	.23**	.15**	.10	.15**	.11*	.15*	–	
12. CCP 2	.11	.10	.16**	.12	.18**	.25**	.17*	.17**	.18**	.17*	.69**	–
13. CCP 3	.21*	.07	.16*	.10	.26**	.34**	.24**	.21**	.20**	.22**	.68**	.76**

Note. RQ = relationship quality; EC 1–3 = educational capital time points 1–3; Act 1–3 = STEM activities time points 1–3; EI 1–3 = elective intentions in STEM time points 1–3; CCP 1–3 = certainty about career plans time points 1–3.
*$p < .05$, **$p < .01$.

Table 5.3. Model Fit for All Growth Models

Model	Description	χ^2	df	p	CFI	RMSEA	SRMR
1a	Unconditional growth EC	0.00	1	1.000	1.00	.00	.00
1b	Conditional growth EC on RQ	1.77	3	.622	1.00	.00	.03
2a	Unconditional growth Act	1.13	1	.288	1.00	.01	.01
2b	Parallel growth Act & EC	21.93	7	.003	.98	.05	.04
2c	Unconditional growth EI	0.57	1	.450	1.00	.00	.01
2d	Parallel growth EI & EC	15.27	7	.033	.99	.03	.03
2e	Unconditional growth CCP	3.69	1	.055	.99	.05	.02
2f	Parallel growth CCP & EC	11.16	7	.132	.99	.02	.02
3a	Longitudinal mediation Act	23.64	9	.005	.98	.04	.03
3b	Longitudinal mediation EI	17.31	9	.044	.99	.03	.02
3c	Longitudinal mediation CCP	13.31	9	.149	.99	.02	.02

Note. EC = educational capital; RQ = relationship quality; Act = STEM activities; EI = elective intentions in STEM; CCP = certainty about career plans.

educational capital in talented female students? In the unconditional growth model of educational capital, there was no mean growth concerning educational capital over the course of the program as indicated by the nonsignificant mean of the slope factor ($M = 0.01$, $p = .811$). However, there were substantial individual differences between the growth trajectories as indicated by the significant variance of the slope factor (*Var* = 0.34, $p = .004$).

For Research Question 1, we found evidence for our assumption that suitably implemented mentoring is related to an increase of STEM-specific

educational capital. The better the relationship quality was, the more the educational capital increased over time ($\beta = .31$, $p = .008$, one-tailed).

Research Question 2. Is a positive change in STEM-specific educational capital associated with an increase in STEM activities, elective intentions in STEM, and certainty about career plans?

STEM Activities. In the unconditional growth model of STEM activities, there was mean growth for STEM activities over the course of the program as indicated by the significant mean of the slope factor ($M = 0.28$, $p < .001$). The value can be interpreted in the units of the scale. This means that the scale mean improved from 3.79 to 4.07 according to the linear growth model. This is very close to the observed means. Individual differences between the growth trajectories were not significant ($Var = 0.22$, $p = .140$). However, we did not treat significant slope variance as a prerequisite for further analyses as per current recommendations (e.g., LaHuis & Ferguson, 2009).

For Research Question 2, we found evidence in the parallel process latent growth curve model that a positive change in STEM-specific educational capital is associated with an increase of STEM activities ($r = .42$, $p = .013$, one-tailed). For this analysis, two multivariate outliers were detected and excluded from the analyses as they very likely would have biased our results. We reported the lower correlation calculated without these two cases.

Elective Intentions in STEM. In the unconditional growth model of elective intentions in STEM, there was no mean growth concerning elective intentions over the course of the program as indicated by the nonsignificant mean of the slope factor ($M = -0.07$, $p = .14$). Individual differences of the growth trajectories were also not significant ($Var = 0.21$, $p = .119$). However, we did not treat significant slope variance as a prerequisite for further analyses as per current recommendations (e.g., LaHuis & Ferguson, 2009).

For Research Question 2, we found evidence in the parallel process latent growth curve model that a positive change of STEM-specific educational capital is associated with an increase in elective intentions in STEM ($r = .37$, $p = .022$, one-tailed).

Certainty About Career Plans. In the unconditional growth model of certainty about career plans, there was mean growth concerning certainty about career plans over the course of the program as indicated by the significant mean of the slope factor ($M = 0.20$, $p < .001$). The value can be interpreted in the units of the scale. This means the scale mean improved from 3.59 to 3.80 according to the linear growth model. This is very close to the observed means. Individual differences between the growth trajectories were not significant ($Var = 0.29$, $p = .148$). However, we did not treat significant slope variance as a prerequisite for further recommendations (e.g., LaHuis & Ferguson, 2009).

For Research Question 2, we did not find convincing evidence in the parallel process latent growth curve model that a positive change of STEM-specific educational capital is associated with an increase of certainty about career plans. The correlation between the two slope factors was only marginally significant ($r = .26$, $p = .079$, one-tailed).

Research Question 3: Is suitably implemented online mentoring (operationalized via relationship quality) indirectly related to an increase in STEM activities, elective intentions in STEM, and certainty about career plans via an increase in educational capital? We calculated the 90% confidence intervals of the indirect effects using percentile bootstrapping (Bollen & Stine, 1990). Ninety percent confidence intervals were appropriate (instead of 95% intervals) as our research questions are directional. Percentile bootstrapping has been shown to provide a better compromise between type-1 and type-2 errors for evaluating mediation than other methods such as bias-corrected bootstrapping (Falk & Biesanz, 2015; Fritz, Taylor, & MacKinnon, 2012). Should the confidence interval contain 0, the effect is not significant. To confirm the results, we also used the joint significance test as recommended by Fritz et al. (2012).

STEM Activities. We found evidence for our assumption that suitably implemented mentoring is related to an increase of STEM activities via an increase in STEM-specific educational capital as indicated by the significant indirect effect (.123, 90% CI [.014, .630]). We confirmed the result with the joint significance method. Relationship quality was positively related to the change in educational capital ($\beta = .30$, $p = .009$, one-tailed); and the change in educational capital was positively related to the change in STEM activities ($\beta = .41$, $p = .020$, one-tailed). As in the parallel process model, the same two multivariate outliers were detected and excluded from the analyses, as they very likely would have biased our results. We reported the lower coefficients without these two cases.

Elective Intentions in STEM. We also found evidence for our assumption that suitably implemented mentoring is related to an increase in elective intentions in STEM via an increase in STEM-specific educational capital as indicated by the significant indirect effect (.101, 90% CI [.002, .491]). We confirmed the result with the joint significance method. Relationship quality was positively related to the change in educational capital ($\beta = .29$, $p = .010$, one-tailed); and the change in educational capital was positively related to the development of elective intentions ($\beta = .35$, $p = .034$, one-tailed).

Certainty About Career Plans. We did not find evidence for our assumption that suitably implemented mentoring is related to an increase of certainty about career plans via an increase of STEM-specific educational capital as indicated by the small and nonsignificant indirect effect (.041, 90% CI [−.054, .270]). We confirmed the result with the joint significance method. Relationship quality was positively related to the change in educational capital ($\beta = .27$, $p = .012$, one-tailed). However, the change in

educational capital was not positively related to the change in certainty about career plans ($\beta = .15$, $p = .204$, one-tailed). There was, however, a positive direct relation between relationship quality and the change in certainty about career plans ($\beta = .33$, $p = .045$, one-tailed).

Discussion

For talented girls, mentoring can have a positive influence on various factors (e.g., elective intentions, certainty about career plans, confidence in their own STEM skills) that, in turn, can encourage them to select courses of study and professions in STEM (Stoeger et al., 2016; Stout, Dasgupta, Hunsinger, & McManus, 2011). In this way, mentoring can help increase the low participation rates of girls in STEM. This applies in particular for online mentoring thanks to its temporal and locational flexibility. However, there is, as yet, scant knowledge about the mechanisms of action at play in (online) mentoring for talented girls in STEM. Improving the effectiveness of mentoring provisions requires a better understanding of the mechanisms of action involved in mentoring. The relatively low effect sizes reported for mentoring in the meta-analytical literature (e.g., DuBois et al., 2002; DuBois et al., 2011; Eby et al., 2008; Eby et al., 2013) make clear that this is an important desideratum in mentoring research and practice. In our study, we therefore investigated three questions that deal with the mechanisms of action in online mentoring for talented girls in STEM.

Earlier research showed that girls' learning environments are less facilitative of their learning in STEM than boys' environments are for boys (Ceci et al., 2009; van den Hurk et al., 2019). Girls' inauspicious learning environments even persist when they show very high interest and very good performance in STEM (Stoeger et al., 2016). Therefore, it seems possible that favorable changes to learning environments could yield positive mentoring effects for girls in particular. In order to answer this question, we first examined whether suitably implemented online mentoring (operationalized via relationship quality) would be related to a positive change in the STEM-related learning environments of talented female students (operationalized via STEM-specific educational capital). We found evidence for this assumption. The more positively the mentees of the online mentoring program rated the quality of their relationship with their mentor, the more their STEM-related educational capital increased over the course of the 1-year mentoring program.

It is interesting to note that positive changes in the learning environment were not uniformly apparent for all mentees. Rather, positive changes were conditional on a high perceived relationship quality. For effecting positive changes in STEM-related learning environments, attending only to the selection of suitable mentors (i.e., successful female role models in STEM) and relevant structural and organizational characteristics of successful mentoring (e.g., adequate duration and frequency of mentee–mentor

communication as well as training and supervision of mentors) appeared to be insufficient. This became apparent in our examination of the CyberMentor program. Therefore, measures should also be implemented to ensure that mentee–mentor relationship quality is as positive as possible.

Facilitating good relationships between mentees and mentors starts before they even meet one another. It is important that mentees and mentors be matched who are as similar to one another as possible (e.g., with respect to their STEM and personal interests). The more similar mentees and mentors are to one another, the more positive the assessments of the quality of their relationships tend to be (Allen & Eby, 2003; Huston & Burgess, 1979). It appears, moreover, that relationship quality is also influenced by the contents about which mentees and mentors communicate. Kern, Harrison, Custer, and Mehta (2019) showed that the discussions of certain topics (e.g., family, friends, school, or future plans) had a positive effect on the quality of relationships. However, the results reported by Kern et al. (2019) were for a mentoring program designed to enhance students' school engagement. Future studies will need to clarify the extent to which these results can be transferred to online mentoring for talented girls in STEM and whether certain communication topics will have a positive influence on the assessment of relationship quality in such programs.

In a second step, we investigated whether positive changes in the learning environment and positive changes in the program's targeted mentoring outcomes are associated. Specifically, we assessed whether positive changes in the learning environment are accompanied by (a) an increase in STEM activities, (b) an increase in elective intentions in STEM, and (c) an increase in certainty about career plans. The findings were affirmative. The more positively the STEM-related learning environment of the mentees developed over the course of the 1-year mentoring program, the more positive the developments were for the three mentoring outcomes, although the correlation for certainty about career plans was only marginally significant.

The scale designs may help explain the marginal significance of the correlations between positive changes in the learning environment and certainty about career plans. The scale for recording the learning environment was worded specifically for the STEM domain. The scale for assessing certainty about career plans was worded without any domain specificity and thus without any reference to STEM. Improvements in the STEM-related learning environment should be more likely to be accompanied by positive changes in mentoring outcomes that are directly related to STEM such as elective intentions in STEM or STEM activities. Moreover, the program design intended for participants to communicate primarily about STEM. Whether the relationship between the STEM-related learning environment and the proportion of STEM-focused communication is indeed positive— as to be expected in light of the program design—could be assessed via quantitative text analyses (e.g., Pennebaker, Boyd, Jordan, & Blackburn, 2015) of the participants' email, forum, and chat communication on the

platform or via a self-report survey of the participants' communication topics.

In a final step, we examined the interplay of the mechanisms of action investigated in Research Questions 1 and 2. Specifically, we examined whether suitably implemented online mentoring (operationalized via relationship quality) indirectly relates to an increase in STEM activities, elective intentions in STEM, and certainty about career plans in STEM via positive STEM-related environmental changes (operationalized as increases in STEM-related educational capital). Evidence for the assumption was found for STEM activities and for elective intentions in STEM. The more positively mentees evaluated the quality of their relationship with their mentor, the more positively their STEM-related learning environment changed, which was associated with positive changes in STEM activities and elective intentions in STEM while controlling for relationship quality. For reasons discussed in the limitations, our results provide no direct empirical evidence for a causal chain from relationship quality to the development of these outcome variables via educational capital. However, the observed results are consistent with such an assumption. Future studies should test the assumption with a different research design.

For certainty about career plans, we did not find evidence for this mechanism of action. As already indicated above, the circumstance may reflect the difference between the STEM-related learning-environment scale and the general—not-STEM-related—scale for certainty about career plans. It should be emphasized again, however, that certainty about career plans increased over the course of the mentoring program—even though, as the results for Research Question 3 show, mechanisms of action other than for STEM activities and elective intentions in STEM seem to be responsible for this. Future studies will be required to clarify such additional mechanisms of action. A closer look at the influence of communication contents might be promising here. It is conceivable, for example, that an increase in certainty about career plans could be caused by, among other things, the volume of discussions on courses of study, occupations, and career paths (also independently of STEM).

In sum, a suite of aspects appears to have been important for achieving the STEM-specific goals of the online mentoring program we examined. In addition to the program's structural and organizational aspects and participants' relationship quality, changes in the girls' STEM-related environments were also important. The latter factor had been largely overlooked in earlier research studies. Numerous studies note the unfavorable characteristics of girls' and women's environments for STEM (e.g., Ceci et al., 2009; van den Hurk et al., 2019). Findings also make clear that positive characteristics of educational capital are essential for the talent development of women in STEM (Ziegler, Debatin, & Stoeger, 2019). Research on (online) mentoring has, however—to the best of our knowledge—not yet taken into account propitious environmental changes as a vehicle for

achieving goals in a mentoring program focused on talent development in STEM.

A more precise understanding of these changes would therefore certainly be helpful for improving mentoring programs in the future. Future studies should therefore examine which aspects of mentoring positively change the STEM-related environments of talented girls. For example, it should be clarified whether regular communication with the mentor is sufficient to this end, or whether communication with as many other program participants as possible is also necessary. In the program we examined, participants were not restricted to dyadic mentee–mentor interaction. Rather, the program facilitated multifaceted communication among participants on a platform on which up to 800 mentees and their mentors take part in the program each year. The members-only platform enables discussions with a large number of higher-status role models (i.e., with mentors) as well as with a large number of same-status role models (i.e., with mentee peers). Partaking in both types of discussions is regarded as particularly important in the area of STEM promotion for girls (Dasgupta, 2011). Future studies should clarify, for example, whether the extent and type of networking with other participants have an influence on changes in the girls' STEM-related learning environments. In this context, it would also be interesting to see whether networks with higher-status or same-status role models are more influential. Finally, research is needed on the influence of participants' communication contents and the affective valence of such communication.

Limitations. Although our study provides new insights, various limitations should be taken into account. Despite the statistically significant results, our models indicate only small to medium effect sizes. For this reason, studies will need to examine the replicability of the mechanisms of action we found. Another weakness of our study is the use of questionnaires. Especially with regard to elective intentions in STEM, it would be desirable to also track actual choices made in STEM in future studies. One possibility would be to ask the girls at the end of the program whether they would like to participate in events in the STEM area (e.g., summer programs or lectures in STEM) and to ask them to register for them. Participants' STEM activities could also be queried concretely at the end of the program. Finally, the assumption that relationship quality is the best available proxy of appropriately implemented online mentoring should be more thoroughly investigated. Various other aspects are also likely to help determine positive changes in STEM-related learning environments within the framework of online mentoring programs for STEM. For example, studies indicate that online mentoring for girls in STEM is more successful if the participants communicate primarily about program-relevant content (Stoeger et al., 2016). The degree of networking with other program participants also seems to influence the effectiveness of mentoring in the STEM field (Stoeger, Hopp, & Ziegler, 2017). In future studies it would therefore

be important to consider not only the relationship quality but also other variables and their influence on STEM-related environmental changes—as well as improvements in mentoring outcomes.

In order to realistically assess the additional explanatory contribution of these variables, as many of them as possible should be examined simultaneously. In addition, such research should be carried out with mentoring programs that take into account important structural and organizational characteristics of successful mentoring (e.g., duration and frequency of contact or training and supervision of mentors), as we did in this study. Attending to such a context is essential for ensuring that peripheral factors are being held constant. Only then can a research design shed light on the importance of the hitherto overlooked factors of successful mentoring for explaining changes in STEM-related environments and for mentoring outcomes.

Finally, the parallel process latent growth curve approach as well as our retrospective measurement of the relationship quality lack appropriate temporal sequencing for a stronger evaluation of our mediation assumption (e.g., von Soest & Hagtvet, 2011). Therefore, any causal statements in general and assumptions of mediation can be only based on theoretical considerations and the pattern of correlations that is consistent with the hypotheses. Future studies should aim for such temporal sequencing and ideally multiple assessments of relationship quality during the course of the mentoring program.

Implications for Policy and Practice. Even if the results of our study can only be used to a limited extent to formulate implications for policy and practice due to the rather low effect sizes, it seems essential to pay close attention to the learning environment when planning interventions. This study and the aforementioned findings on the unfavorable STEM-related learning environments of talented girls speak strongly in favor of this recommendation. For a long time, interventions focused on changes in individual characteristics, such as confidence in one's own abilities or STEM-related interest. Especially for talented girls who are already very interested in STEM, the problem seems to lie rather in unfavorable environmental conditions (Stoeger et al., 2016). Girls often lack suitable female role models in their environment; and even when they show interest in STEM, they receive fewer learning and support opportunities than boys (Stoeger et al., 2012). Mentoring programs such as CyberMentor help redress this endemic gender inequity in STEM talent development.

However, the successful implementation of such programs requires paying careful attention to various findings. Studies show, for example, that mentoring programs only have a positive effect if they have a sufficient duration—ideally of at least 1 year. Furthermore, it seems essential that mentee–mentor communication is regular, if possible on a weekly basis. At the same time, it is also important to ensure that communication remains focused around program-relevant content and that participants'

relationship quality remains positive. Only when these and various other characteristics of successful mentoring known from the research literature are fulfilled can it be assumed—as our study also shows—that mentoring makes a contribution to positive environmental changes. However, a glance at extant mentoring practices unfortunately shows that these characteristics are partially or fully lacking in many programs due to restraints of time or funding. A first step would therefore be to pay more attention to such known characteristics of successful mentoring when planning the financing and implementation of mentoring programs.

Yet it must also be kept in mind that online mentoring programs—even when their implementation fulfills all known criteria of successful mentoring—may not, on their own, suffice to permanently improve the situation of talented girls in STEM. Even if such educational provisions effect positive changes in a segment of the environment of STEM-interested girls—in certain environments, so to speak—they generally find themselves enmeshed in many other less advantageous environments. For example, girls who participate in programs such as CyberMentor may find a STEM-friendly learning environment on the platform, but then return to STEM-inimical environments outside of the program. They might be teased by their friends for participating in such a program, subtly undermined in their STEM interest by the condescending remark of a teacher, or told by parents not to neglect supposedly more important themes for their futures. Girls who are exposed to such hostile environments probably benefit less from participating in a mentoring program than girls who participate in the same program and also experience STEM friendliness in their other daily environments. It is therefore essential to integrate as many environments as possible into the STEM promotion of girls. For example, it would be conceivable to link programs such as CyberMentor with in-school offerings and to involve parents and peers in the mentoring.

Whether the integration of more aspects of girls' environments into the mentoring experience makes sense still needs to be scientifically verified. To this end, the development of mentees participating in online mentoring programs with and without the inclusion of additional environments (e.g., school, family, or peers) should be compared. Ideally, the developmental processes of these two groups would also be compared with those of a wait-list control group of girls who have also registered for the same program (with or without the integration of additional environmental aspects) but will only start participating 1 year later (see Stoeger et al., 2013).

This proposal brings us to an important demand with which we wish to close this article. Mentoring programs or other educational provisions designed to improve the situation of girls in STEM should be designed as sustainably as possible. This requires, among other things, sufficient and longer-term financing. Only then can as many criteria of successful mentoring as possible be sufficiently taken into account during implementation

and only then can serious accompanying research take place, the results of which can be continuously used to improve existing programs.

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