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How to foster students' motivation in mathematics and science classes and promote students' STEM career choice. A study in Swiss high schools

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ABSTRACT

Programs aimed at increasing the attractiveness of STEM professions should encompass women as well as men. Based on that premise our study focuses on the research question: How can high school students' motivation in mathematics, physics, and chemistry classes be increased and what impact does students' high motivation in math and science have on a career choice in STEM? The study is embedded in the Eccles' expectancy-value model. Applying structural equation modeling, it provides evidence that fostering students' motivation has a positive impact on their willingness to choose a STEM study field. Moreover, the results show that classes supporting students' motivation increase the intrinsic value of math and science among students and the probability of a STEM career choice.

1. Introduction

Although participation rates of men and women in secondary and tertiary education and their educational success have largely evened out (Rodax & Rodax, 1996) the gender disparities in the preference of study and occupational fields have remained surprisingly stable in most western societies (OECD, 2012; Scott, Crompton, & Lyonette, 2010).[1] Women are catching up in demanding occupations in the social and health care sectors, while they continue to avoid male-dominated occupations in the areas of sciences, technology, engineering, and math (STEM) (Jarman, Blackburn, & Racko, 2012; OECD 2012; Smith, 2011). The persistent gender segregation in career choice according to "so called female- and male-occupations" (Leemann & Keck, 2005, p. 73, translation by authors) leads not only to the reproduction of anachronistic gender stereotypes but also to shortfalls in the recruitment of employees in the sciences and technology sectors. This is an alarming situation in a knowledge society that increasingly depends on technological competencies (e.g. Anger, Demary, Koppel, & Plünnecke, 2013; Sadler, Sonnert, Hazari, & Tai, 2012; Quaiser-Pohl, 2012). The concern is even more serious since young men's willingness to study STEM subjects (esp. physics, IT, and engineering) has recently been dwindling (Becker,

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[1] A few fields of study record an increase in female enrollment. However, in Switzerland and in other western countries the female share only increases slowly and these increases do not occur across all the STEM fields.

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2010; Smith, 2011; Xie & Achen, 2009). To increase the attractiveness of STEM professions generally, research should no longer be limited to women but include men as well. This especially holds true for research seeking the educational determinants of unequal career choices, because students' interest in school subjects like math and science has great influence on their decision for or against a professional career in a STEM field (cf. e.g. Eccles & Wigfield, 2002; Gottfredson, 2002). Thus, our study focuses on the instructional design of mathematics, physics, and chemistry high school classes that explicitly foster female *and* male students' motivation. We assume that an instructional design that takes care of the different motivational needs of male *and* female students may not only foster the interests of both genders in the respective school subjects, but may also contribute to a reduction of the gender disparity in career choice.

2. Theoretical background

2.1. Motivational issues in math and science classes

The underrepresentation of women in science and technical occupations can be explained by a range of factors extending from macro-sociological and economic to evolutionary-biological and neuro-psychological approaches (Blakemore, Berenbaum, & Liben, 2009; Buchmann, DiPrete, & McDaniel, 2008; Ceci, Williams, & Barnett, 2009). All of these approaches have revealed significant determinants of gender segregation in career choice (Halpern et al., 2007). However, for the development of reforms it is useful to focus on areas that can be influenced through interventions. This includes, specifically, the pedagogical realm. Aside from the family, math and science education offers a starting point to counter the low willingness of women *and* men to choose a course of study in the STEM fields.

In their extensive interdisciplinary and causally argued analysis of the research literature, Ceci et al. (2009, p. 229ff.) attribute the greatest explanatory power for the underrepresentation of women in STEM professions to motivational issues. What remains an open question in their analysis is which factors influence motivation. While they mention the proximal conditions of family and school, the methodological aspects of the motivational instructional design of math and science classes remain ignored. This seems unjustified since a number of studies have shown that motivational instructional design offers a potent approach for raising the interest of students in math and science education (Aeschlimann, Herzog, & Makarova, 2015a, 2015b; Murphy & Whitelegg, 2006). These studies are based on the well-substantiated fact that the interests of boys and girls in science classes partly differ (e.g. Eisenberg, Martin, & Fabes, 1996; Rustemeyer, 2009). While male students show greater interest in technical questions, female students are more interested in contextual aspects, such as meaning in everyday life or application in medicine, environment, energy, and nutrition (Miller, Blessing, & Schwartz, 2006; Murphy & Whitelegg, 2006). Underlying these findings are gender divergent preferences for relationships with humans and objects: women prefer activities that involve humans, while for men interactions with objects have a higher priority (e.g. Ceci et al., 2009). Unfortunately, these pre- and extra-scholastic conditioned differences between boys' and girls' interests find too little consideration in school teaching, where students' everyday experiences are especially important for the comprehension of the subject matter. In particular, the differing interests of girls in math and science subjects are seldom taken into account in educational settings (e.g., Hoffmann, 2002; OECD, 2009).

Interest in a subject is generally an important precondition for academic learning (e.g. Köller, Baumert, & Schnabel, 2001; Krapp, 1999). Moreover, it has been shown that girls' interest in science strongly correlates with their academic achievements in these subjects (Blakemore et al., 2009; Weinburgh, 1995). Again, this results also applies to boys, because one cannot assume that boys always have the kind of everyday experience that motivates them for science classes. Thus, an important starting point for interventional actions aimed at raising girls' and boys' interest in STEM careers lies in the motivational design of math and science classes.

2.2. Motivational design of math and science classes

The improvement of motivational conditions in math and science classes has emerged as a promising intervention strategy in gaining more women *and* men for STEM occupations. In investigating motivational improvement, the present study makes use of the expectancy-value theory of Eccles (Eccles, 2007; Eccles & Wigfield, 2002; Eccles, Wigfield, & Schiefele, 1998), whereby the expectancy component encompasses the self-perception of one's own achievement in a particular subject.[2] Two important aspects of the value component are interest in and enjoyment of the subject. Furthermore, the Eccles-model also serves as an explanatory framework for school- and occupational decisions (Eccles & Wigfield, 2002). It can be shown that in addition to performance, academic self-concept and subject interest are relevant determinants in students' selection of secondary school majors (Eccles & Wigfield, 2002; Nagy et al., 2008; Watermann & Maaz, 2004). Similar mechanisms seem to be crucial for career choice, even when majors selection in secondary school cannot be equated with career choice or choice of majors in higher education (cf. Nagy, Trautwein, Baumert, Köller, & Garrett, 2006).

[2] It should be noted that while performance expectations and academic self-concept can theoretically be distinguished, empirically the two constructs are not distinguishable (cf. e.g. Nagy et al., 2006).

Motivational issues in math and science classes have been addressed in a number of studies applying different theoretical frameworks mainly focusing on the motivational issues of female students (Eisenberg et al., 1996; Halpern et al., 2007; Hoffmann, 2002; Murphy & Whitelegg, 2006; Rustemeyer, 2009). We assume that this literature can be used to establish criteria for a motivationally conducive instructional design that is not only appropriate for female students but for male students as well. A literature review revealed four aspects that can contribute to the improvement of students' motivation particularly in math and science classes; these are listed below.

(1) Providing *information about career opportunities* in the STEM fields by showing that STEM occupations are pursued by women as well as men and by providing the students with career role models (Frome, Alfeld, Eccles, & Barber, 2006; Halpern et al., 2007; Makarova & Herzog, 2014). Addressing occupations and professional fields is also useful because women's self-efficacy beliefs about gender-atypical occupations are significantly lower than those about gender-typical careers (Hackett, 1995).

(2) Insuring *comprehensible teaching* of math and sciences for students (Murphy & Whitelegg, 2006; Zohar & Sela, 2003). The material should be thoroughly presented and explained; sufficient time needs to be allocated to students to absorb the material; the format of presentation should be varied when comprehension problems emerge.

(3) Providing *individual support to* students. Various studies report that a good relationship with the teacher is essential especially for female students in math and science classes (Lee, 2002; Zohar & Sela, 2003). What is captured here is the need to obtain personal support and individual encouragement in case of learning problems, a criteria of good teaching that is important for male students as well.

(4) Connecting the subject-specific matters with *everyday experience* of male *and* female *students*. Examples and illustrations should not come from specialized fields of activity or activities which are not familiar to girls or boys but rather from students' real-life day-to-day contexts (cf. e.g. Meece, Glienke, & Burg, 2006; Ziegler, Schirner, Schimke, & Stoeger, 2010).

In summary, we can state that math and science classes designed around these four principles have been proven to increase female students' motivation and to enhance their performance in math and science. We suggest that such classes are able to reduce the gender stereotypical choices of study and career field and could motivate and enable young women to pursue a career in a STEM field. In addition, we assume that by adjusting these four teaching principles accordingly, the motivation of boys in the math and science classes and their choice of a STEM career and study fields can be influenced positively as well.

An approach such as ours, which focuses on the motivational design of math and science classes, can be seen as an alternative to the widely held opinion that career decisions in STEM-fields are determined by same-sex role models. According to Beller and Gafni (1996, p. 375), for example, "role models, both in and out of school, are a crucial factor in encouraging the greater involvement of the girls in mathematics and the sciences". However, scientific studies that confirm a positive relationship between teacher gender and students' learning motivation are very rare; moreover they mostly deny such a relationship (cf. e.g. Martin & Marsh, 2005). The findings of a UK study for example revealed "that the gender of teachers had little apparent effect on the academic motivation and engagement of either boys and girls (Carrington et al., 2007, p. 397). Due to the unclear state of research we will include teacher gender as a control variable in our study.

3. Research questions

The main goal of this study was to analyze the impact of the motivational design of mathematics, physics and chemistry classes in high schools on the choice of a STEM field as a major field of study by students who are close to obtaining their high-school diploma (Matura; university entrance diploma). Based on the theoretical and empirical framework of the study, we expected that math and science classes satisfying the four design criteria described earlier would positively affect learning motivation and STEM field of study choices among female *and* male high school students. The main questions of the study were:

(1) To what extent does a motivational design of classes in mathematics, physics, and chemistry influence students' learning motivation and their achievement in math and science? (2) To what extent do students' individual characteristics (i.e. students' learning motivation and their academic achievements in mathematics, physics and chemistry) promote students' choice of the STEM study field?

4. Methods

4.1. Study design and sampling

For the analysis of the research question we used data from a Swiss National Science Foundation funded project (Nr. 4060-129279) on gender-atypical choices in occupations and study fields by young women. A total of 167 high school classes from the German-speaking part of Switzerland participated in the project. By means of an extensive standardized survey, data were collected on math and science lessons and on the intended field of study at university for 3032 male and female students in the spring of 2011. Students from 55 classes were polled on the subject of mathematics (32.9%), students from 52 classes on the subject of chemistry (31.1%), and students from 60 classes on the subject of physics (36.0%). Altogether 81.4% of the students were taught by a male teacher and 18.6% by a female teacher. The classes analyzed comprised on

Table 1
Descriptive analysis of the students' individual characteristics.

	Items	Scale	*M*	*SD*	Alpha	Item examples
Interest	3	1–5	3.17	0.98	0.65	I am interested in Maths/Physics/Chemistry.
Enjoyment[a]	3	1–5	2.89	1.20	0.90	1. I enjoy the subject. 2. The subject aroused my curiosity.
Self-perception of achievement[a]	3	1–5	2.81	1.05	0.88	1. The subject is easy for me. 2. I feel confident in my abilities with the subject.
Grades in Maths, Physics, and Chemistry	3	1–9[b]	6.21	1.26	0.78	What was the last grade on your report card in Maths/Physics/Chemistry?

Notes: M = Mean, *SD* = Standard deviation.
[a] The wording of the items was adjusted to the corresponding subject matter.
[b] Mark 1 = worst – Mark 6 = best (incl. half notes).

Table 2
Descriptive analyses of lesson characteristics.

	Items	Scale	*M*	*SD*	ICC_1	Item examples
Individual teacher support	4	1–5	2.87	0.92	0.25	1. My teacher is interested in me and in my progress in the subject. 2. My teacher helps me when I am struggling.
Teaching competency	4	1–5	3.08	0.80	0.46	1. My teacher can explain well. 2. My teacher designs interesting and exciting lessons.
Real-life connections	4	1–4	2.45	0.66	0.40	1. When a new concept is introduced, relevant real-life examples are discussed. 2. Experiments are usually connected with everyday objects and phenomena (e.g. household appliances).

Notes: M = Mean, *SD* = Standard deviation, ICC_1 = Intra-Class-Correlation.

average 18 students (range: 8–28 students per class, *SD* = 4); 55.6% of the young people were female. The average age of the survey respondents was 19 years at the time of the survey (*SD* = 1).

4.2. Measurements

Among *students' individual characteristics* two constructs were considered: (i) students' learning motivation and (ii) their academic achievement. The *learning motivation* of high school students was operationalized using three subscales: a) students' self-perception of achievement in math and science (SBFI 2010), b) students' interest in math and science, and c) students' enjoyment of math and science (Stake, 2006; adapted). *Academic achievement* of students was measured by students' grades in mathematics, physics, and chemistry. Tables 1 and 2 show descriptive statistics and item examples for the measures.

Instructional design of classes was operationalized using three four-item subscales with five- and four-level answer options respectively,[3] capturing the dimensions of a) *teachers' individual support* (Herzog, Labudde, Neuenschwander, Violi, & Gerber, 1997; Stake, 2006), b) *comprehensible teaching* (Stake, 2006), and c) *connection to students' everyday experiences* (Herzog et al., 1997). In addition, the index *information about STEM professions* (NSF, 2007) consisting of seven items regarding the coverage of professional opportunities in the STEM field was included in the study (e.g., 'In the lessons the teacher dealt with the topic "Professional opportunities in the areas of sciences and mathematics" ; min. = 0, max. = 7, answer positions between "not covered in the lessons" (0) and "covered in the lessons" (1)).

Calculation of the inter-class correlations (ICC1) showed that the motivational instructional design of classes vary systematically between classes. At 25–46, a substantial share of the total variance was between the classes, which confirmed a significant hierarchical nesting of the data and necessitated a multilevel modeling approach in the analysis of the data (i.a. Raudenbush & Bryk 2002). The genders of the math and science teachers were also included in the analyses.

STEM field study choice. To assess the field of study choice, the high school students were asked about their preference for study majors at a university or at a university of applied sciences after the successful completion of high school. The answers were coded by the gender-type of the field of study based on degrees obtained at Swiss universities in the year 2010 (BFS, 2012). A field of study was labeled as female-atypical (male-typical) when the share of women obtaining a degree in the respective field was below 30.0% (Aeschlimann et al., 2015a, 2015b). In our sample, mathematics, statistics, IT, sciences,

[3] Since in the models presented all items are mean-centered the different response scales are irrelevant.

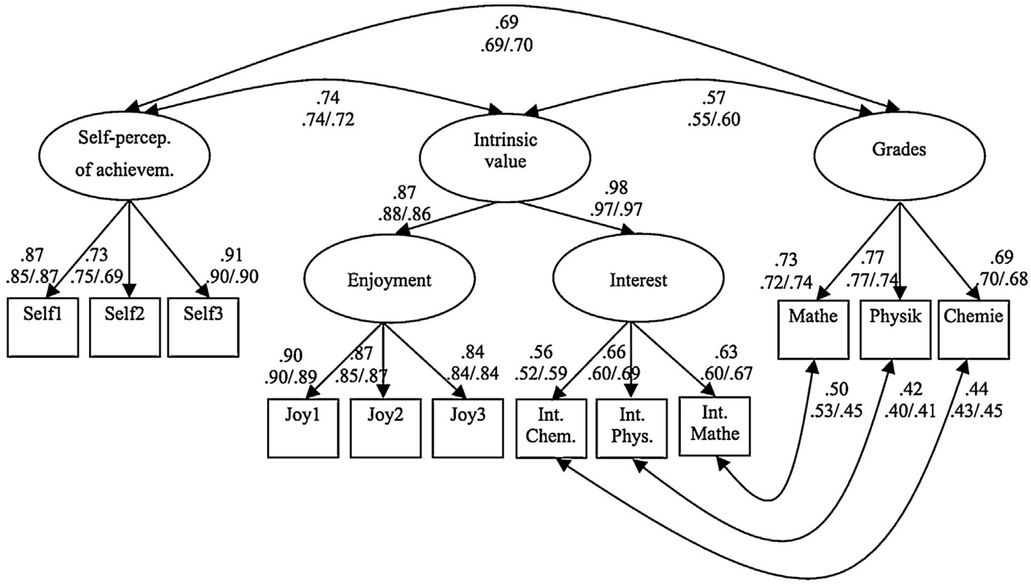

Fig. 1. Model individual characteristics. 2998 female and male students in 167 classes, 1670 female students in 166 classes and 1324 male students in 167 classes; correlations and factor weights significant at $p < 0.001$, Estimator: MLR, upper value: total, 1. value: female students, 2. value: male students.

engineering and architecture fall into this category. Since all listed fields of study can be assigned to the STEM area, the category is henceforth labeled STEM field study choice. All other fields of study were assigned to the category 'non-STEM study choice'. The multivariate analyses were conducted with the dichotomous variable STEM field study choice (STEM field study choice = category 1; non-STEM study choice = reference category 0).

4.3. Statistical procedures

All constructs were first tested on their dimensionality through factor analysis. The constructs on individual characteristics were separately tested for the students, while taking into account the hierarchical data structure and resulting dependency of the data. The constructs on the lessons were tested by means of multilevel factor analysis (KMFA) (Brown, 2006). These procedures allowed for the simultaneous examination of the factor structure on the individual and class levels.

To answer research question 1, we then estimated a Model 1 on the relationship between class- and individual characteristics and STEM field of study choice. Research question 2 was answered in Model 2. In that model we tested the relationship of the independent variables of the students' individual characteristics with the dependent variable students' STEM field choice separately for men and women.

All models were specified as structural equation models. The constructs of the class level – as well as those at student level – were, whenever possible, latently modeled. The MLR estimation procedure was used as the statistical technique for model estimation and model assessment. For more complex models, however, we reverted to the WLSM-estimator (Muthén & Muthén, 1998-2010). The share of missing values was under 2% for the individual variables. Using the FIML procedure, we were also able to include respondents with missing values (Allison, 2003). The model evaluation was carried out with incremental (CFI and TLI; acceptable > 0.90, good > 0.97) and absolute fit-indices (RMSEA and SRMR; acceptable < 0.08, good < 0.05) (Hu & Bentler, 1999). In addition, we report the statistical significance of the *Likelihood-Ratio* $\chi 2$*- goodness of fit test*.

5. Results

5.1. Models

Models of students' individual characteristics. The model of students' individual characteristics had an acceptable fit ($\chi^2(46) = 290.497$; $p = 0.000$; CFI = 0.981; TLI = 0.973; RMSEA = 0.042; $\text{SRMR}_{\text{within}} = 0.028$) for the female students ($\chi^2(46) = 223.866$; $p = 0.000$; CFI = 0.976; TLI = 0.966; RMSEA = 0.048; $\text{SRMR}_{\text{within}} = 0.034$) as well as for the male students ($\chi^2(46) = 192.788$; $p = 0.000$; CFI = 0.977; TLI = 0.966; RMSEA = 0.049; $\text{SRMR}_{\text{within}} = 0.031$; see Fig. 1). The factor weights[4] as

[4] Standardized weights (or paths) are depicted, which were obtained through the stdyx command in M*plus*.

well as the correlations were nearly identical for the two sexes, which suggests that it is a homogeneous model, relevant for both men and women. Due to the high correlation between the constructs *students' interest in math and science* and *students' enjoyment of math and science classes,* these variables were summarized in one second-order-factor, *intrinsic value of* math and science. As can be seen in Fig. 1, the individual factors were highly positively correlated, i.e. students with higher overall learning motivation had greater academic achievement (correlations between 0.55 and 0.74 for female students and between 0.60 and 0.72 for male students). Fault correlations were permitted between the items of students' subject interest and students' academic achievement. This specification of fault correlations appears justified since in the respective items the same subjects are named.

Models of instructional design of math and science classes. The estimations for the instructional design of classes were modeled simultaneously at the individual level and at the class level. At the class level the factor structure analyzed the influences of class perceptions. The model exhibited a good fit ($\chi^2(100)$ = 441.801; $p < 0.000$; CFI = 0.968; TLI = 0.958; RMSEA = 0.034; $SRMR_{within}$ = 0.030; $SRMR_{between}$ = 0.093; see Fig. 2). The factor weightings were very high throughout ($\lambda \geq 0.85$). Also, the dimensions teachers' *individual support* and *comprehensible teaching* had a high correlation coefficient of 0.74, showing that at the class level individual support from the teacher was associated with comprehensible teaching. However, the *connection with students' everyday experiences* at the class level emerged as an independent dimension.

5.2. Model 1: relationship between instructional design of classes and students' individual characteristics

A multilevel structural equation model was specified to answer research question 1 (χ^2 *(188)* = 579.324; $p = 0.000$; RMSEA = 0.023; CFI = 0.949; TLI = 0.937; $SRMR_{within}$ = 0.029; $SRMR_{between}$ = 0.104), which analyzed the influence of the instructional design of classes (class level) on the students' individual characteristics (individual level). Initially it can be seen that at the class level no significant relationships existed between the gender of the teacher and the perception of comprehensibility of teaching, connection of classes to students' everyday experiences, or the information about STEM professions at the class level. However, based on perceptions at the class level, the individual support of the male teachers was perceived as being significantly lower than that of their female colleagues ($\beta = -0.17$). In addition, significant paths can be established from comprehensible teaching on the students' intrinsic value of math and science ($\beta = 0.28$) and on students' self-perception of achievement by male and female students ($\beta = 0.32$), as well as from the information about STEM professions on the intrinsic value of math and science ($\beta = 0.52$) and on students' academic achievement ($\beta = 0.35$). Female and male students of teachers with highly comprehensible teaching and high levels of information about STEM professions also reported a higher intrinsic value of math and science. For teachers' individual support as well as for the connection to students' everyday experiences, no significant relationships with students' individual characteristics could be established at the class level. Analyzing the influence of instructional design of classes on choice of study majors, only the information about STEM professions was significant ($\beta = 0.50$). The more teachers inform students about STEM professions in their lessons, the more likely are students to decide for studies in a STEM field (see Fig. 3).

5.3. Model 2: relationship between the students' individual characteristics and their choice of field of study

A structural equation model was estimated for answering research question 2 on the influence of individual characteristics on the students' STEM field choice (see Fig. 4). The following values describe the model fit: $\chi^2(54)$ = 466.869; $p = 0.000$; CFI = 0.952; TLI = 0.931; RMSEA = 0.050; SRMR = 0.025; for the model of female high school students: $\chi^2(54)$ = 306.895; $p = 0.000$; CFI = 0.946; TLI = 0.922; RMSEA = 0.053; SRMR = 0.030; for the model of male high school

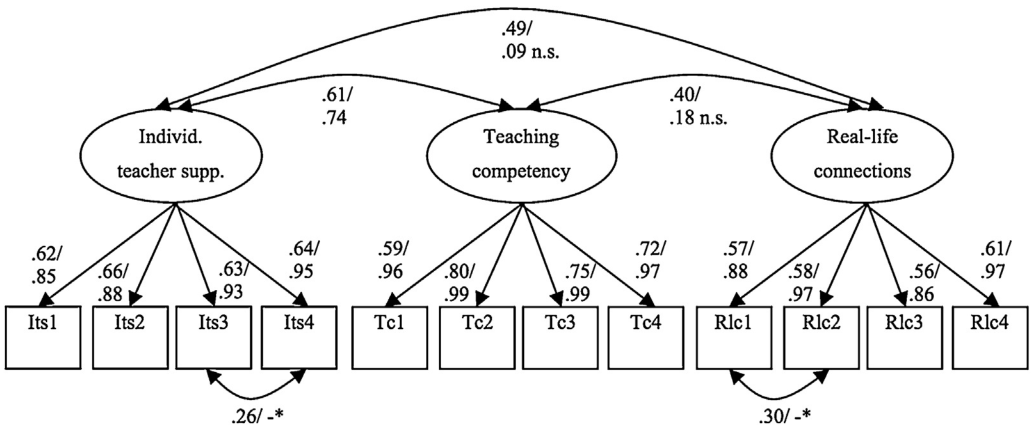

Fig. 2. Model class characteristics. 3011 female and male students in 167 classes; correlations and factor weights significant at $p < 0.001$; Estimator: MLR, 1. value: individual level, 2. value: class level; *fault correlations not estimated on the class level.

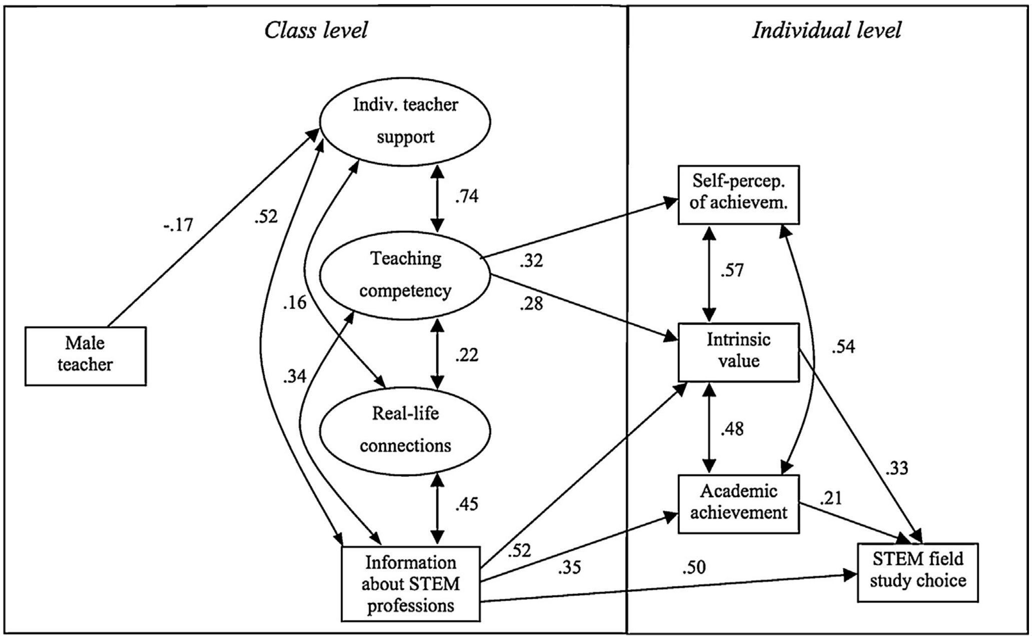

Fig. 3. Relationship between class- and individual characteristics and STEM field of study choice. 3020 male and female students in 167 classes, models not shown, individual factors and individual paths included in the estimation (not shown), factor weights, correlations and paths significant at $p < 0.05$, Estimator: WLSMV.

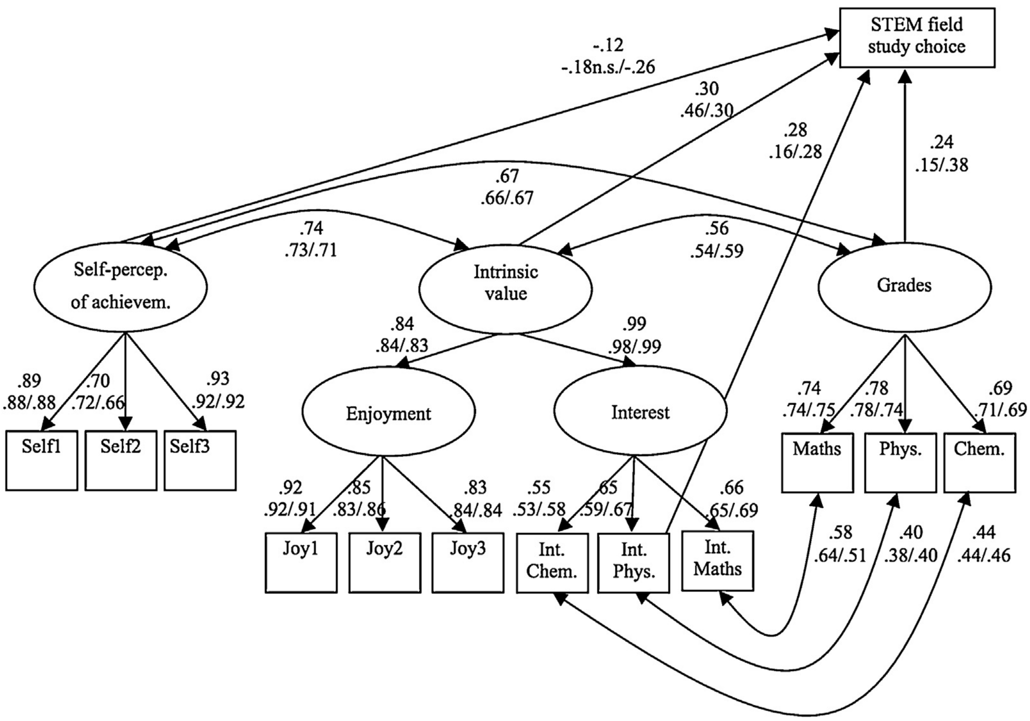

Fig. 4. Relationship between individual characteristics and STEM field of study choice, 3020 female and male students in 167 classes, 1680 female students in 166 classes and 1336 students in 167 classes, factor weights, correlations and paths significant at $p < 0.05$; Estimator WLSMV, upper value: total, 1. value: female students, 2. value: male students.

students: $\chi^2(54) = 323.551$; $p = 0.000$; CFI = 0.923; TLI = 0.889; RMSEA = 0.061; SRMR = 0.030. Based on the model for female high school students we can see that female students with a higher intrinsic value were inclined to choose a STEM field with greater probability ($\beta = 0.46$). That effect seemed particularly strong for physics ($\beta = 0.16$). High interest in physics raised the probability of choosing a STEM field of study when all other factors were controlled for. Both findings can be replicated for male high school students with some marginal differences: a weaker influence of the intrinsic value on the STEM field choice ($\beta = 0.30$) and a stronger influence of interest in physics ($\beta = 0.28$).

Similar effects could be observed with regard to students' academic achievement. High achievement in mathematics, physics, and chemistry heightened the likelihood of choosing a STEM field of study for female high school students ($\beta = 0.15$) as well as – and more strongly so – for male high school students ($\beta = 0.38$). A less clear picture emerged with regard to self-perception of achievement. Counter to our prediction, the effect was negative, although only in the entire model and the model for male high school students ($\beta = -0.26$).

6. Discussion

The starting point of our study was the assumption that a motivational design of math and science classes can affect the attractiveness and accessibility of a STEM career choice. Considering the unchanged low share of women in STEM fields of study as well as the most recently observable lower rates of males choosing a STEM field, intervention measures are needed that can be effective for both sexes. High school education in math and the sciences that needs to satisfy both sexes in a coeducational setting can benefit especially. Inspired by the Eccles' expectancy-value model aimed at academic achievement and professional choice (Eccles & Wigfield, 2002; Wigfield & Eccles, 2000), a strategy presents itself, which starts with the improvement of the motivational situation of students of both sexes in math and science classes. Based on existing research, four criteria could be identified that should be conducive to students' motivation. The four criteria are: *information about STEM professions, comprehensible teaching, teachers' individual support of students,* and *connection to students' everyday experiences of math and science.* An instructional design of math and science classes that is aligned with those criteria is not only capable of promoting students' learning motivation but also of heightening their willingness to opt for a STEM field of study.

6.1. Learning motivation

The motivational constructs showed a relationship pattern that is largely in line with existing research (cf. Denissen, Zarrett, & Eccles, 2007; Eccles et al., 1998). The self-perception of academic achievement in mathematics, physics, and chemistry influenced the intrinsic value of those subjects more strongly than the students' actual academic achievements (grades on the report card). As in other studies, the intrinsic value of a subject emerged as a better predictor of academic decisions and, ultimately, of professional choice than the self-perception of achievement (Eccles & Wigfield, 2002; Nagy et al., 2006). The models differed only slightly between the sexes.In line with the meta-analysis by Valentine et al. (2004), no gender differences could be found in the relationship between self-perception of achievement and actual performance. Only for the correlation between the intrinsic value of the subjects and students' academic achievement according to their grades, were the values for female students slightly lower than for male students, a finding which also corresponds with the results of existing studies (Denissen et al., 2007; Schiefele, Krapp, & Schreyer, 1993). Probably the greater willingness of girls to comply with the performance expectations of the school motivates them to exert more effort and therefore obtain better grades even when their interest in the subject is limited.

Instructional design of the classes. The model on instructional design showed a close association between teachers' individual support and comprehensible teaching that can be interpreted as an indicator of 'good teaching practice' (cf. e.g. Helmke, 2012). It could be argued that a motivational design of classes follows the features of effective teaching while also taking into account the unique characteristics of gender, including pre- and extra-scholastic differential interests.

The gender of the teacher did not play a significant role in the motivational design of classes. While male teachers exhibited significantly lower scores compared to their female colleagues in terms of individual support, overall the teacher's gender had little significance. These findings go in line with Miller et al. (2006) who reported that female students did not report a lack of female teachers in the subjects mathematics, physics, and chemistry who can serve as role models as is sometimes argued. However, they did complain of a lack of sufficient attention to the particularities of their everyday experience and the resulting interest deficiencies.

STEM field study choice. The *analysis of students' individual characteristics* for STEM field of study choice uncovered complex patterns. The intrinsic value of the subjects and students' actual performance in the subjects had a positive influence. For female students, the motivational component was distinctly more important than their actual performance, while the opposite was true for male students. In addition, the interest in physics constituted a strong determinant in the STEM field of study choice, especially for male students. In light of the small gender differences in mathematics performance levels between the sexes, as shown in recent studies (cf. e.g., Else-Quest, Hyde, & Linn, 2010; Hyde, 2005), the question arises whether physics has become the new obstacle that controls entrance into STEM professions. In a study from the United States, Frome et al. (2006) observed that aside from other factors, not mathematics, but limited interest in physics leads young women to give up their initial interest in male-typical professions.

Further, an unexpected negative connection emerged between the self-perception of performance with the STEM field of study choice. Apparently, boys with high self-perceptions of achievement are less likely to choose a STEM field of study than would be expected, based on the empirical connection between high self-perception of achievement on the one hand and higher grades and a higher intrinsic value on the other. This effect is important as it shows that the STEM field of study choice is not necessarily the first choice even for high school students with high interest and good performance in mathematics, physics, and chemistry.

Even when controlling for *instructional design of classes*, the intrinsic value of the subjects of mathematics, physics, and chemistry was a significant predictor of a STEM field of study choice by high school students. A stronger effect emerged from information on STEM professions and a weaker effect was observed from actual academic performance. Through both those factors, information about STEM professions also influenced field of study choice indirectly. While expected, the strong influence of information about STEM professions on learning motivation and academic performance as well as on the choice of STEM-majors was surprising. However, this result is consistent with the Eccles-model. Referring to differences in human and object orientation, Eccles (2007) highlights how important it is to show young women that science subjects are not oriented toward professional fields that contradict their humanistic orientation: 'If we want to increase the number of females who consider entering physical science and engineering careers, it will be important to help females see that these careers provide opportunities to fulfill their humanistic and people-oriented values and life goals' (Eccles, 2007, p. 208). Classes that inform about STEM professions and that exhibit the quality characteristics of good teaching (especially the teaching competency of the teacher) manage to increase the intrinsic value of the subjects.

Overall, our study shows that improvement of the motivational conditions in mathematics, physics, and chemistry classes through targeted teaching practice not only can raise the learning motivation of high school students, but can also have a positive effect on their willingness to start studies in a STEM field. In light of the growing importance of science professions in our society, this is a hopeful and practice-relevant finding.

Our study is subject to a few limitations. As a cross sectional study it does not allow for reliable conclusions about causal mechanisms. Moreover, we did not collect data on the actual field of study choice but only on the anticipated decision. This is also the case in comparable studies (Nagy et al., 2006; Watt, 2006) but does not invalidate the criticism that the hypothetical study choice does not necessarily reflect the actual choice. Theoretically, we limited our study to the intrinsic value of subjects and did not consider the three other thematic value components (personal, utilitarian and relative costs) by Eccles (e.g., Eccles & Wigfield, 2002). The relative significance of these values in the context of a strategy for motivational math and science classes and for STEM study choice remains to be explored. Finally, we should note that the field of study choice for *both* sexes is determined by multiple factors (Gottfredson, 2002). The design of the math and science lessons explored here is only one of several determinants that affect the field of study choice by male and female high school students. Future research should build on our work to address these issues with new data and methodologies.

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