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How an inquiry-based classroom lesson intervenes in science efficacy, career-orientation and self-determination

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ABSTRACT
Three subscales of the 'Science Motivation Questionnaire II' (SMQII; motivational components: career motivation, self-efficacy and self-determination), with 4 items each, were applied to a sample of 209 secondary school students to monitor the impact of a 3-hour structured inquiry lesson. Four testing points (before, immediately after, 6 and 12 weeks after) were applied. The modified SMQII was factor-analyzed at each testing cycle and the structure confirmed. Only self-determination was shown to be influenced by an inquiry course, while self-efficacy and career motivation did not. Only self-efficacy and career motivation were intercorrelated and also correlated with science subject grades and subsequent achievement. Implications for using the modified SMQII subscales for research and teaching in secondary school are discussed.

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Inquiry-based teaching; science motivation; self-determination

Introduction

Motivation

Young people increasingly show a lower tendency to study science subjects at tertiary levels, due perhaps to increased failures of school science education (Osborne & Dillon, 2008). Lack of motivation, an internal state that arouses, directs and sustains science-learning behavior, is regarded as a major reason (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011). Motivation is considered to produce eagerness to work and learn new information and skills (Glynn, Taasoobshirazi, & Brickman, 2009). This is why environments should be rich in interesting activities, to foster children's curiosity and offer manageable challenges (Meece, 1997), prerequisites that could be met with inquiry-based science lessons. Social cognitive theory, in general, claims that achievement depends heavily on interactions between students' behavior, characteristics (such as self-efficacy and self-determination) and conditions of the learning environment (Bandura, 2001). Perceived self-efficacy is one major motivational component: it refers to the believed self-confidence of students in accomplishing a task (Bandura, 1986). It has been found to predict achievement and career decisions (Britner & Pajares, 2006; Pajares & Schunk, 2001). Another motivational component is self-determination,

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referring to perceived control a student thinks he/she has over his/her learning (Black & Deci, 2000). Self-determination might be enhanced by giving more autonomy to the learner (Palmer, 2005). Science career motivation may closely relate to later career choices involving science. It holds the potential to explain whether students see science as part of their future career perspective a move and beyond their (immediate) grades. According to Glynn et al. (2011), these components are interdependent and constitute a model of motivation, the Science Motivation Questionnaire II (SMQII), derived from social cognitive theory. Compared to students with doubts about their learning capabilities, students who feel well suited for learning or performing a task participate more readily, work harder and persist longer when they encounter difficulties, and achieve at a higher level (Britner, 2008; Schunk & Meece, 2005). Additionally, students with high learning motivation are more likely to achieve academically by engaging in crucial behaviors such as studying, question asking, seeking advice or participating in class (Pajares, 2002; Pajares & Schunk, 2001), features also important for taking part in inquiry-based lessons. Motivation is a crucial tool to foster academic achievement (Britner, 2008; Britner & Pajares, 2001, 2006; Bryan, Glynn, & Kittleson, 2011; Cavallo, Potter, & Rozman, 2004; Glynn, Taasoobshirazi, & Brickman, 2007; Pajares, 1996). An increase in motivation is therefore a major goal for science teaching. If teachers would know which students lack motivation to learn science, and why, lessons could be adapted to foster motivation. To assess motivation for science, a reliable and valid questionnaire is needed.

Inquiry-based science teaching

As Brickman, Gormally, Armstrong, and Hallar (2009) have pointed out, comparing studies of inquiry-based science teaching is somewhat difficult, due to differences in or the lack of a proper definition for inquiry or its level applied, but see Prince and Felder (2007) for an overview of inquiry-like inductive teaching methods. We use Linn, Davis, and Bell's (2004, p. xvi) definition of inquiry-based learning: 'the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching for information, constructing models, debating with peers and forming arguments'. Inquiry teaching is a constructivist form of teaching that uses student-centered activities, where students take an active part in reasoning rather than being allowed to passively receiving information from a lecture. We use 'structured inquiry' or 'level 1' inquiry, where the teacher provides a question and the material and method for investigating it. The students focus on discussing and interpreting their results and connect them to the information background provided through, e.g. texts (see Blanchard et al., 2010 for an overview of the inquiry levels). Cognitive engagement is regarded as a prerequisite for meaningful learning (Jonassen, 2000) and we would like to stress that the active part in inquiry learning is not merely performing experiments but understanding them by active cognitive involvement of the students. The teacher is not the center of attention during class. He plays the role of a guide. He walks around and from time to time questions student teams on what they are doing, why they are doing it or why they decided on this and that answer. He lets them explain their observations and their reasoning without involving other groups. Students work mostly on their own; they follow the working booklet provided by the teacher, but the teacher keeps an eye on their progress. If students give false information to the teacher, the teacher asks further questions to indicate that there is a mistake in their conclusions, helping the group to recognise their mistake and find the right connections to make.

In the socio-constructivistic view of learning, students do not passively absorb information but rather actively modify their existing knowledge, beliefs, interests and goals in accordance with new information (Palmer, 2005). The reconstruction and expansion of knowledge require effort on the part of the learner. Palmer (2005) concludes that motivation is required for learning, as students will not invest effort unless they are motivated to do so. To increase students' motivation, classroom strategies can be used (Palmer, 2005). Inquiry-based learning has been proposed and found to increase students' motivation (Eurydice, 2011; Gibson & Chase, 2002; Tuan, Chin, Tsai, & Cheng, 2005; Wimpey, Wade, & Benson, 2011). Most studies used elongated lesson times. Self-efficacy, for example, was found to be enhanced through problem-based learning (Dunlap, 2005). Patrick, Mantzicopoulos, and Samarapungavan (2009) found that kindergarten children enjoyed science more if they took part in the inquiry lessons and suggest that early inquiry learning could be important for choosing a career in science. Enhancement of motivation through brief interventions is not yet shown for inquiry-based learning to our knowledge. Yet, motivation was shown to be enhanced through brief interventions with other contexts like hands-on learning in the school context (one-day intervention, Marth & Bogner, 2017). The success of our 3-hour inquiry course, in terms of increased and sustainable content knowledge, has already been monitored (Schmid & Bogner, 2014). Students increased their knowledge and were able to recall this knowledge for at least 12 weeks. As a learning benefit, in terms of test-score increase, had already been established (Schmid & Bogner, 2014), our current study focuses on a potential increase in motivation due to participation in a 3-hour inquiry-based lesson. We decided purposely for a brief intervention, as the results will be more beneficial for teachers' daily teaching and evaluating. Teachers often face the problem of a dense syllabus. In project-related workshops on inquiry-based learning with teachers all over Europe, we got the feedback that they often fear that it may lead to time-management problems when they would use student-centered methods like inquiry-based learning in their classroom regularly. However, using it now and then for certain topics would fit their needs to fulfill all of the syllabus within a school year much better. It is normally not up to the teachers to decide for an overall restructuring of teaching style at their school, neither are they given inquiry-based teaching material for topics nor is it up to them to construct the lesson-plans and to decide at which day for how long they teach their subject to, e.g. form block-lessons at a specific day all year long. The more or less only reliable object to their control is how they teach their class in their subject(s). Therefore, we find it more beneficial for science teachers to have access to the analysis of the impact of brief inquiry-based learning scenarios that realistically could be used on their own decision in their class. The less additional work-load is added to the implementation of inquiry-based learning, the lower is the barrier for its more frequent usage in schools. With this clarification of why to analyze if science motivation would be affected by the brief inquiry-based course, we chose the unfortunately uncommon strategy of repeated data acquisition of students motivation over the course of 2 weeks before the intervention, directly afterwards, 6 and 12 weeks after the intervention. With this pattern, short, intermediate and longer term effects can be made visible.

Research question:

1. Are the shortened SMQII subscales appropriate instruments to measure self-efficacy, self-determination and career motivation, and do these variables reflect distinct and specific factors?
2. Is the structure of the SMQII subscales consistent over time?
3. Can students' career motivation, self-efficacy and self-determination be influenced through participation in a structured inquiry lesson?
4. Are self-efficacy, self-determination and career motivation interrelated?
5. Are self-efficacy, self-determination, career motivation related to achievement; and are they related to grades in science (biology and physics) and non-science subjects (native language)?

Materials and methods

Science Motivation Questionnaire

SMQII (Glynn et al., 2009, 2011) was described as a tool to evaluate the effectiveness of instructional strategies and materials designed to increase students' motivation. It provides information on an individual's motivation to learn science. The SMQII is therefore a tool for investigating motivation to learn science as well as the interaction of motivation with instructional methods (Glynn et al., 2011). So far, the SMQII has only been used with post-secondary school students. As the question of motivation to learn science is a crucial issue during school time, we applied this instrument to secondary school students. All SMQII items followed a 5-point Likert scale ranging from 1 (totally reject) to 5 (totally agree). As Glynn et al. (2011) had stressed that further validation is always needed, we focused on an adaptation from 5 to 4 items per subscale in order to reduce the overall item number. This is especially beneficial for keeping adolescents focused on filling in questionnaires, especially if the study consists of several questionnaires and their repeated application. The applied subscales of the SMQII were 'self-efficacy', 'self-determination' and 'career motivation'. The subscales 'intrinsic motivation' and 'grade motivation' were not used. A-priori exclusion was justified with either similar meaning of items or comprehension difficulties of students in the pilot study. As the SMQII can be used to track changes in students' science motivation during a course (Glynn et al., 2011), we applied the SMQII four times: T0: before the course, T1: directly after the course, T2: 6 weeks after and T3: 12 weeks after the course (Figure 1). The second retention test we regard as reflecting a potential long-term impact of our course. Additional variables were students' content knowledge (17 items) and their latest subject grades (biology, physics and native language).

Sample and intervention

We examined 209 secondary school students' motivation for science and the effects of a single inquiry unit upon it using a quasi-experimental design (Mertens, 2010). Although the applied course was originally designed for international use within the EU project PATHWAY, the sample for this study was drawn from German schools within the federal state of Bavaria only. Data were collected from 4 different schools and 10 different classes. Students were in grade-9 of the Gymnasium (4 years of elementary school and 5 years of Gymnasium (secondary school)). It is intended to house high achievers and enables graduates access to universities with no further examinations. Medium achievers attend the Realschule (junior high school) for 5 years, while the Hauptschule (secondary modern school) is designed for low achievers. Participants of this study are thus considered to represent the high-achieving portion of a cohort. The schools and classes represented the diversity of the country and were not special in any way. Students were 15.1 years old (SD = 0.55) with 44.23% girls and 55.77% boys. We decided on a 3-hour program, as it reflects day-to-day school life more realistically (Crawford, 2000) than longer programs. Normal science lessons last 45 minutes. Our structured inquiry-based science course 'The hearing of sound' combined biology with physics in a student-centered way of learning. A description of a prior version of the course can be found on the PATHWAY's website (http://pathway.ea.gr/sites/default/files/D2_8.pdf). Differently to their regular biology lessons, students worked independently in teams of four with the help of a working booklet and a box of materials to use for setting up experiments mentioned in the texts of the booklet. The teacher only helped on demand, for instance, with technical problems and narrowed down problems raised by a group, leading the students of the group to find the answers to their questions by themselves. Thus, the teacher facilitated the learning rather than providing the knowledge. Inquiry-based learning is still not common in German classrooms due to time and class management conflicts with short time slots and average class sizes of 24.3 students (Statistische Ämter des Bundes und der Länder, 2013). Experiments typically are demonstrated by teachers. If students do experiments, they often follow recipes in 'cook book' style, with planned sequences and fixed material while an interpretation of results is discussed beforehand (see, e.g. Blanchard et al., 2010). Our students were novices with inquiry learning. The course lasted for 3 consecutive hours on one day during a regular school week. Inquiry-based lessons of this kind are rather uncommon in German biology classes (see above).

The hands-on material was presented in a big box in front of the class. Students needed to fetch the experimental setups autonomously and work with them following information provided in the workbook. Provided materials consisted of laptops with free software, tuning forks, metallophones, paper clips, rulers, boxes, rubber bands, paper cards, etc. The workbook asked questions about the phenomenon to be investigated, provided information about comparisons to known phenomena similar to the one to be investigated (e.g. lever system already known from a playground-see-saw) and contained the description of experiments as well as questions regarding the interpretation of results, i.e. level-1 inquiry (see above). The classroom teacher did not accompany the lesson unit in order to reduce

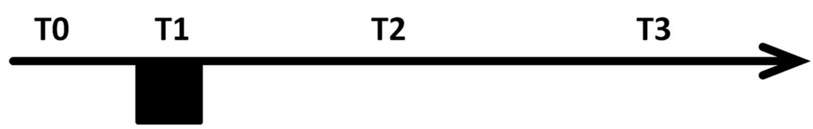

Figure 1. Schedule of questionnaires. Black area = lesson. T0 = 2 weeks prior; T1 = directly after; T2 = 6 weeks after and T3 = 12 weeks after the lesson.

bias due to teaching style or changes to the teaching unit. The instructor of our lesson unit was the same for all classes and was unknown to all students. In the weeks before and after the intervention, classroom teachers continued to teach on their regular topics. The topic of the human ear, acoustics, hearing and comparable topics were taught neither beforehand nor afterwards by the teachers so that the content was brought to students solely through the 3-hour inquiry-based lesson.

Statistics

For statistical analyses, we used SPSS 20.0. For the factor extraction of the SMQII, a principal axis factoring (PAF) was used. Three factors were identified using the Kaiser–Guttmann rule. The Scree plot supported the three-factor solutions. We used direct oblimin rotation for facilitated interpretation. The mean scores of each SMQII-subscale were normally distributed according to the QQ-Plots. In case of repeated measurement ANOVA and correlations, mean scores were applied. For correlation calculations, Bonferroni corrections were applied (alpha/number of tests applied). List-wise exclusion of missing data was applied for all analyses. Number of subjects per analysis varied from 95 to 209 due to absence and to students skipping questions on some of the subtests in the time series.

Results

Structure analysis of the SMQII

The pre-test SMQII-questionnaire (T0) was factor-analyzed (principal axes factor analysis (PAF) with direct oblimin rotation). Using the Kaiser–Guttman rule, three clear factors with an eigenvalue greater than 1 were identified: career motivation (C), self-determination (SD) and self-efficacy (SE) (Table 1). All factors accounted for a total accumulated variance of 51.08% (T0, $n = 209$), and a variance per factor of F1: 29.3, F2: 14.2, F3: 7.6. Bartlett's test of sphericity was significant ($\chi^2 = 880.43$, df = 66, $p < .001$) and the Kaiser–Meyer–Olkin value is considered good (KMO = .80; Field, 2005, p. 640).

Table 1. Factor loadings from the PAF with direct oblimin rotation of the pre-test values of the SMQ (T0) (scores <.3 are suppressed).

Item	Abb.	Factor 1	Factor 2	Factor 3
My career will involve science (C4)	C4	.813		
Understanding science will benefit me in my career (C3)	C3	.758		
Learning science will help me get a good job (C1)	C1	.682		
I will use science problem-solving skills in my career (C5)	C5	.658		
I put enough effort into learning science (SD1)	SD1		.685	−.336
I spend a lot of time learning science (SD2)	SD2		.652	
I prepare well for science tests and labs (SD3)	SD3		.638	
I study hard to learn science (SD4)	SD4		.595	
I am sure I can understand science (SE5)	SE5			.746
I believe I can master science knowledge and skills (SE4)	SE4			.704
I am confident I will do well on science tests (SE2)	SE2			.640
I am confident I will do well on science labs and projects (SE3)	SE3			.552
Cronbach's α	–	.838	.730	.779

Note: n(T0) = 209. Abbreviations in bracket derivate from random presentation of items during the pre-test and merely have internal meaning.

The subscales of the SMQII (T0) are split into three distinct subscales as described by Glynn et al. (2011). Factor loadings ranged from 0.552 to 0.813, with one cross-loading above 0.3. Reducing the number of items did not affect the threefold structure (Table 1).

Analysis of consistency of the SMQII structure

We applied the PAF analysis for all subsequent testing time-points (T1–T3), revealing the same structure each time. Bartlett's test of sphericity was significant (T1: $\chi^2 = 872.89$, df = 66, $p < .001$; T2: $\chi^2 = 761.03$, df = 66, $p < .001$; T3: $\chi^2 = 798.73$, df = 66, $p < .001$) and the Kaiser–Meyer–Olkin value considered good (T1: KMO = .80, T2: KMO = .78, T3: KMO = .80; Field, 2005, p. 640). No cross-loading above 0.3 occurred. For the three additional testing time-points, the total explained cumulative variance was above 50%: T1: 51.54% ($n = 201$); T2: 53.75% ($n = 163$); T3: 55.39% ($n = 155$), and a range (T1–T3) of variance per factor of F1: 29.3–34.0, F2: 13.4–15.5, F3: 6.4–8.8. Cronbach's α ranged between 0.730 and 0.857 (T0 – T3) (Table 2). Values between 0.7 and 0.8 are considered good, especially with only four items per scale (Field, 2005, p. 668).

The influence of a structured inquiry course on science motivation was analyzed by comparing the cohorts' scores at the four testing time-points (T0 – T3; Figure 2).

Each subscale was analyzed by applying repeated measurement ANOVA. It revealed a consistent subscale rating over time for career motivation and self-efficacy (career: $F(3, 279) = 2.14$, $p =$ n.s., partial $\eta^2 = 0.22$, $n = 94$); self-efficacy: applying Mauchly's test indicated that the assumption of sphericity had been violated (app. $\chi^2(5) = 18.8$, $p < .05$). Therefore, degrees of freedom were corrected by using Greenhouse–Geisser estimates of sphericity ($\varepsilon = .886$), $F(2.66, 260.46) = 1.13$, $p =$ n.s., partial $\eta^2 = .011$, $n = 99$). Self-determination, however, changed significantly over time ($F(3, 297) = 6.93$, $p < .001$, partial $\eta^2 = .065$, $n = 100$). From pre-test to directly after the lesson, self-determination was

Table 2. Factor loadings from the PAFs with direct oblimin rotation of the post-test (T1) and the two retention tests (T2, T3).

		T1			T2			T3		
Item	Abb.	C	SD	SE	C	SD	SE	C	SD	SE
My career will involve science (C4)	C4	.860			.778			.888		
Understanding science will benefit me in my career (C3)	C3	.804			.871			.809		
Learning science will help me get a good job (C1)	C1	.719			.734			.529		
I will use science problem-solving skills in my career (C5)	C5	.715			.649			.702		
I put enough effort into learning science (SD1)	SD1		.549			.694			.573	
I spend a lot of time learning science (SD2)	SD2		.660			.759			.728	
I prepare well for science tests and labs (SD3)	SD3		.643			.727			.678	
I study hard to learn science (SD4)	SD4		.549			.595			.747	
I am sure I can understand science (SE5)	SE5			.719			.736			.866
I believe I can master science knowledge and skills (SE4)	SE4			.846			.593			.752
I am confident I will do well on science tests (SE2)	SE2			.643			.771			.611
I am confident I will do well on science labs and projects (SE3)	SE3			.534			.599			.514
Cronbach's α		.857	.736	.782	.855	.785	.777	.814	.756	.814

Notes: Factor loadings below .3 are not shown. n(T1) = 201, n(T2) = 163, n(T3) = 155. Order of items as ordered due to their loading during T0 (Table 1). Abbreviations in bracket refer to random presentation of items during the pre-test and have internal meaning only.

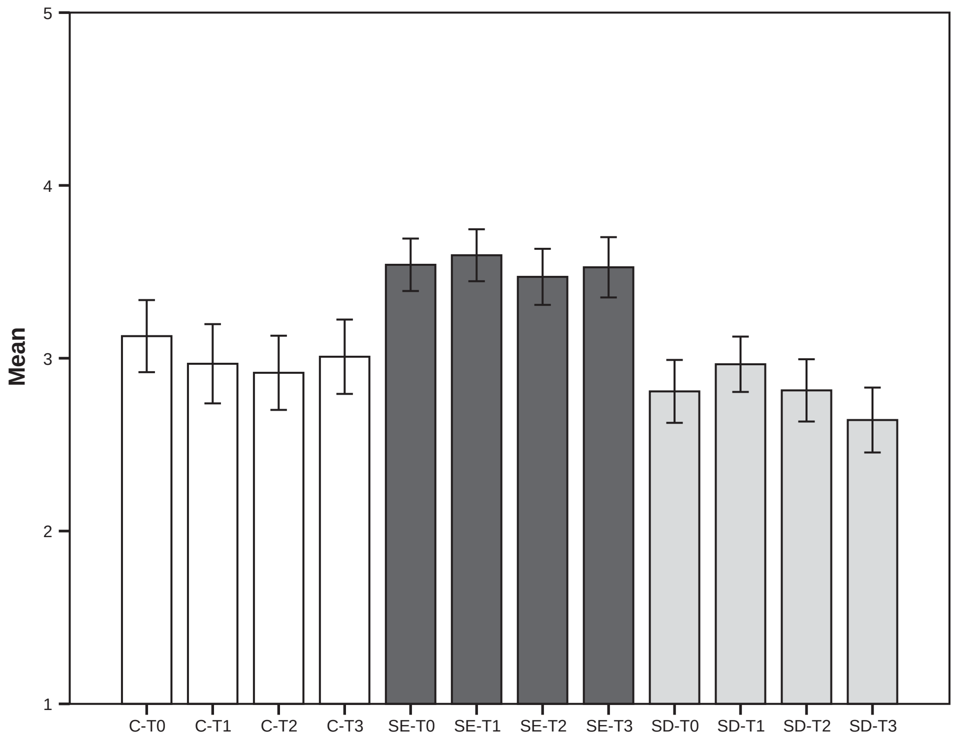

Figure 2. The SMQII factors measured over a period of 14 weeks: C = career motivation, SE = self-efficacy, SD = self-determination. Two weeks before (T0), directly after (lesson; T1), 6 weeks after (T2) and 12 weeks after the lesson (T3). A 5-point Likert scale was used: Maximum 5, minimum 1. Mean scores of each subscale are displayed.

increased (SD T0–T1: $F(1, 99) = 5.21$, $p = .025$, partial $\eta^2 = 0.05$, $n = 100$). After 6 weeks, students fell back to their pre-lesson level (SD T0–T2: $F(1, 99)= 0.058$, $p =$ n.s., partial $\eta^2 = 0.001$, $n = 100$) and after 12 weeks SD was even below the pre-lesson level (SD T0–T3: $F(1, 99) = 4.249$, $p = .042$, partial $\eta^2 = 0.041$, $n = 100$).

Correlations of the SMQII with other variables

To analyze the intercorrelations of the SMQII subscales, and its correlations with students' grade and knowledge score, we applied Pearson's correlation coefficient r and Bonferroni correction, $n = 95$. For career motivation and self-efficacy only, the mean scores of the pre-test (T0) were used in all correlations, as the rating of all subscales remained constant over all four measurement points (see above). For self-determination, all four testing time-points were used, as students' rating changed over time (see above).

The intercorrelations of the subscales yielded significant values only for career motivation (T0) with self-efficacy (T0) ($p < .001$, $r = 0.54$, $r^2 = 0.29$). Self-determination (T0–T3) did not correlate with career motivation (T0) (T0: $r = 0.14$, $r^2 = 0.02$, T1: $r = 0.16$, $r^2 = 0.03$, T2: $r = 0.2$, $r^2 = 0.04$, T3: $r = 0.08$, $r^2 = 0.01$; all $p =$ n.s.) nor with self-efficacy (T0) (T0: $r = 0.00$, $r^2 = 0.00$, T1: r=-0.023, $r^2 = 0.00$, T2: $r = 0.13$, $r^2 = 0.02$, T3: $r = 0.02$ $r^2 = 0.00$; all $p =$ n.s.).

Table 3. Correlations of the mean scores (T0) of the SMQ-subscales with students' mean knowledge scores (K-T0–T3).

		K-T0	K-T1	K-T2	K-T3
T0-C	*r*	.17	.23	.34*	.30*
T0-SE	*r*	.26	.21	.35*	.35*
T0-SD	*r*	−.13	−.05	−.02	.02

Notes: Pearson correlation index *r*; $N = 95$. Due to Bonferroni correction *p*-values below .0042 are considered significant and indicated with an asterisk.

To analyze the correlation between science motivation and students' knowledge score before and after the inquiry course, Pearson's correlation coefficient was calculated for each subscale of the SMQII (T0) and the four measuring time-points of the knowledge score (T0–T3; Table 3).

Career motivation correlated significantly with the knowledge score 6 weeks after the inquiry course and continues to show significance 12 weeks later as well (T2: $r = 0.34$, $r^2 = 0.12$, $p = .001$, T3: $r = 0.30$, $r^2 = 0.09$, $p = .003$): there was a small tendency for students with high knowledge scores in the retention tests to report a high motivation for a science career. Before and directly after the course, career motivation did not correlate with knowledge levels (T0: $r = .17$, $r^2 = 0.03$, $p =$ n.s., T1: $r = 0.23$, $r^2 = 0.05$, $p =$ n.s.).

Self-efficacy: Similar to career motivation, self-efficacy is significantly correlated with knowledge levels 6 and 12 weeks after completion of our intervention (T2: $r = 0.35$, $r^2 = 0.12$, $p < .001$, T3: $r = 0.35$, $r^2 = 0.12$, $p < .001$) but did not before and directly after the course (T0: $r = 0.26$, $r^2 = 0.07$, $p =$ n.s.; T1: $r = 0.21$, $r^2 = 0.04$, $p =$ n.s.).

Self-determination (T0) did not correlate throughout the four measuring time-points with the knowledge scores (SDT0*KT0: $r = -0.13$, $r^2 = 0.02$; SDT0*KT1: $r = -0.05$, $r^2 = 0.00$; SDT0*KT2: $r = -0.02$, $r^2 = 0.00$; SDT0*KT3: $r = 0.02$, $r^2 = 0.00$; all $p =$ n.s.; $n = 95$). This is the case, regardless of self-determination changing between T0 and T3 (SDT1*KT0: $r = -0.12$, $r^2 = 0.01$; SDT1*KT1: $r = 0.04$, $r^2 = 0.00$; SDT1*KT2: $r = -0.06$, $r^2 = 0.00$; SDT1*KT3: $r = -0.03$, $r^2 = 0.00$; SDT2*KT0: $r = -0.02$, $r^2 = 0.00$; SDT2*KT1: $r = 0.16$, $r^2 = 0.03$; SDT2*KT2: $r = -0.07$, $r^2 = 0.00$; SDT2*KT3: $r = -0.07$, $r^2 = 0.00$; SDT3*KT0: $r = -0.10$, $r^2 = 0.01$; SDT3*KT1: $r = -0.12$, $r^2 = 0.01$; SDT3*KT2: $r = 0.02$, $r^2 = 0.00$; SDT3*KT3: $r = 0.05$, $r^2 = 0.00$; all $p =$ n.s.; $n = 95$). Thus, students' rating of high or low self-determination is independent from their individual content knowledge scores.

The correlation of the SMQII subscales and students' grade was also analyzed (Table 4). The biology and physics grades both correlated significantly with career motivation and self-efficacy (CT0*bio: $r = 0.4$, $r^2 = 0.16$, $p < .001$; CT0*phys: $r = 0.36$, $r^2 = 0.13$, $p < .001$; SET0*bio: $r = 0.54$, $r^2 = 0.29$, $p < .001$; SET0*phys: $r = 0.49$, $r^2 = 0.24$, $p < .001$). Thus, good grades in biology or physics tend to be linked with high scores

Table 4. Correlation of the mean scores of the SMQ-subscales with students' mean subject grades.

		Bio	Phys	Native language
T0-C	*r*	.39*	.36*	.03
T0-SE	*r*	.54*	.49*	.09
T0-SD	*r*	.24	.05	.17

Notes: SMQ-data from pre-test (T0). Pearson correlation index *r*; $N = 95$. Due to Bonferroni correction *p*-values below .0056 are considered significant and indicated with an asterisk.

in career motivation and high scores in self-efficacy. On the other hand, self-determination did not correlate significantly with the science subject grades, when taking Bonferroni correction into account (SDT0*bio: $r = 0.24$, $r^2 = 0.06$, $p =$ n.s.; SDT0*phys: $r = 0.05$, $r^2 = 0.00$, $p =$ n.s.). Good grades in biology and physics, therefore, do not indicate whether a student possesses high or low self-determination. As a control, we also included the grade of the native language, which had, as expected, no significant correlation with the SMQII subscales (CT0*NL: $r = 0.03$, $r^2 = 0.00$; SeT0*NL: $r = 0.09$, $r^2 = 0.01$; SDT0*NL: $r = 0.17$, $r^2 = 0.03$; all $p =$ n.s.), indicating that they are indeed connected to science subjects only.

Discussion

Correlations of motivational components – only partially

Only self-efficacy and career motivation correlate with each other, self-determination does not correlate with them. This is quite in contrast to Glynn et al. (2011) reporting correlations between all three factors but in line with Schumm and Bogner (2016). In our case, then, the motivational components do not seem mutually supportive. Throughout our analyses, self-determination showed other response patterns than career motivation and self-efficacy, indicating that the motivational components do indeed differ (see discussion below). However, the positive correlation between self-efficacy and career motivation is in line with Stake and Mares (2001), where high school students with a strong sense of capabilities prior to inquiry courses showed greater expectations for a successful science career. Considering science in future career plans, therefore, seems connected to self-confidence in students' ability and skills to master (school) science content. Similarly, Gwilliam and Betz (2001) reported self-efficacy as a predictor for later course selection and career preference. Believing in one's capabilities, therefore, indicates individual willingness to select corresponding career plans. As self-determination behaved differently in all aspects of our analysis, the discussion is split between self-efficacy & career motivation and self-determination.

Career motivation and self-efficacy

Effects of a 3-hour inquiry lesson on career motivation and self-efficacy. Career motivation and self-efficacy are not influenced by a short (3 h) inquiry course. Both subscales remain unchanged over a period of 14 weeks, despite the inquiry course. We conclude that those two subscales reflect a general rating, not specific to a certain course or a particular day (as their items intend), and that career motivation and self-efficacy are rather constant. To affect these variables, explicit teaching about science careers and self-efficacy may be needed. For instance, even a one-year long inquiry course in college Physics has been found to not intervene with self-efficacy (Cavallo et al., 2004). On the other hand, Brickman et al. (2009) described attending a term-long inquiry lab course as leading to an increase in self-confidence. Self-efficacy is believed to be strongest influenced by the interpretation of previous performance (Bandura, 1986, 1997). According to Schunk (1985) and Schunk and Meece (2005), self-efficacy is raised by success and lowered by failure, but occasional failure (or success) after some success (or failure) is unlikely to impact self-efficacy levels. This could explain why our rather short inquiry lesson did not impact students' self-efficacy – the experience gathered during the course probably produced an insufficient impact on the general self-efficacy for learning science. Stake and Mares (2001; program 1) showed science confidence scores to be stable from the pre- to post-test, but to increase 6 months later: science confidence in high ability students was affected in the long term by a 4-week inquiry-based course. However, although it explicitly included the topic of career options in science, career motivation was only increased in the short term. On the other hand when using the SMQII, Marth and Bogner (2017) found that the motivational component self-confidence (merged through factor analysis of self-efficacy and intrinsic motivation) was increased short term through a day-long hands-on intervention. Taken together, our results add to the still unclear picture of the influence of inquiry teaching on self-efficacy and career motivation.

Relationship of achievement, career motivation and self-efficacy. Students with lower long-term achievement had lower career motivation and self-efficacy, and vice versa. Long-term achievement (i.e. retention; T2, T3) apparently gives hints on students' opinion about the involvement of science in their later career. Glynn et al. (2007) similarly found positive correlations between career motivation and science grade point average (GPA). Students of our study, who had high self-efficacy, were more likely to earn higher knowledge scores. This is in line with Stake and Mares (2001) where high school students with strong general beliefs in their individual abilities appeared to profit more from their 4-week inquiry summer course. Britner and Pajares (2001) also found self-efficacy in middle school students to be a predictor of science achievement. In agreement with Bryan et al. (2011), we see self-efficacy as related to achievement. Thus, high achievers hold higher self-confidence (and vice versa). Generally, self-efficacy is known to mediate the effects of prior achievement, knowledge and skills on later achievement (Schunk, 1985). That the correlations directly after the lesson (T1) were non-significant may be explained by the fact that directly after the course relatively high content knowledge scores can be achieved by all students. However, in the long term (T2, T3) only the knowledge score of 'good' students (deep processing) can remain high after 6 or 12 weeks. As the school class is then 'split' into those students still able to remember and score high on the knowledge test, and those unable to do so, the knowledge score then correlates significantly with career motivation and self-efficacy.

Relationship of grades, career motivation and self-efficacy. Similar to our findings of career motivation and self-efficacy on achievement, students who had good grades in biology or physics also scored high in career motivation and self-efficacy. The link between career motivation and student grades is not surprising as probably those students strong in science would feel better prepared or have higher aspiration to aim for a science career. Neither of both motivational components correlated with the native language grade, indicating a criterion-related validity for these subscales. For example, Zusho, Pintrich, and Coppola (2003) described self-efficacy as predicting final course grades in a college chemistry course. In their 2011 study, Glynn et al. reported self-efficacy as the subscale showing the highest correlation with students' GPA – a finding we could confirm, both biology and physics grades relating more strongly to self-efficacy than to career motivation. Glynn et al. (2011) used grades based on students' achievement during the observed semester while we used grades based on students' achievement prior to our course. We therefore conclude that self-efficacy is not only a predictor of future grades (and test achievement), because it leads students to work harder and persist longer on hard tasks (Britner, 2008); but that previous grades also indicate students' self-efficacy for this subject. As a control, we also included the grade of the native language, which did, as expected, not correlate with the SMQII subscales, indicating a connection to the science subjects only.

Self-determination

Effects of a 3-hour inquiry lesson on self-determination. Self-determination was found to be affected positively by our inquiry course, although this increase lasted only in the short term. Therefore, self-determination seems to be more easily influenced by current subject topics or events, than career motivation or self-efficacy. This may be explained by the circumstance that students' thoughts, e.g. on their later career, are something that is rather built up from diverse resources in their daily life and is therefore more 'robust' to new information or experiences. That may also be true for self-efficacy, as evaluating one's own skills in respect to a subject (science) is probably based on long-time observations during the last school year(s) (Bandura, 1986, 1997). On the other hand, in the subscale of self-determination, students are asked to evaluate how much they learn and prepare for a subject (science). This is a question that students can rate differently each day as the question of learning effort can be applied each day anew – as students invest effort each day, likely depending on subject, topic, teacher and so on – and therefore new 'information' is added to the question of learning effort each day. On the other hand, 'information' adding to career decisions or self-efficacy may be encountered rather less frequently in school; e.g. topics regarding science careers, or test-results where students get feedback on their performance in a certain topic or subject. Taken together, it seems that the self-determination subscale can be answered according to rather daily fluctuating experiences despite their general formulation. For instance, 'I study hard to learn science' – sometimes I do, sometimes I do not; depending on other circumstances on that day/week. The items of career motivation and self-efficacy rather require opinions regarding the (late) future (career), or are based on a relatively long history of experience of passed exams (self-efficacy) – e.g. 'Learning science will help me get a good job' or 'I am confident I will do well on science tests'. Additionally, it could be argued if the subscale of self-determination really measures self-determination in its diversity, as the item wording concentrates mostly on time and effort investment to learn science, but less on perceived control a student thinks he/she has over his/her learning.

Relationship of self-determination, grades and achievement. Contrary to Glynn et al. (2011), in our study self-determination was found to be independent from secondary school students' acquired content knowledge as well as from their science subject grades. Similar findings were made by Schumm and Bogner (2016), where the subscale self-determination did not correlate with school students' grades either.

Therefore, it seems that secondary school students' belief in investing and learning enough for science subjects (i.e. taking control over their learning; high self-determination) is reflected neither by test scores nor by grades. It seems that grades and achievement in biology and physics therefore cannot indicate high or low self-determination in secondary school students. Further research in this direction would be very interesting.

Looking closer at self-determination, our secondary school students of 15 years (SD = 0.55; 44.23% girls) differed from the undergraduate university sample of Glynn et al. (2011; science and non-science majors, no data on age provided). This discrepancy may explain the differing results for self-determination. Above all, school classes contain all kinds of students, those interested in science, and those who are less or not at all interested in them. University classes mainly consist of young people who actively and freely chose (a) a certain subject area and (b) are determined to invest their time and capacities to learn this subject. Furthermore, as students do not actively choose to be in school, they cannot choose to only learn subjects or topics interesting to them. Therefore, instead of learning because they are interested, they may rather learn 'for the teacher' in trying to please his or her expectancies. Third, students in upper secondary school are generally younger than first and second semester university students. Additionally, we assume that school students form much stronger social bonds with their teachers than undergraduate university students do to their lecturers, because of the many social aspects of school classes (e.g. relatively small groups of up to ~30 students [Sekretariat der Ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland, 2013], social misbehavior is condemned, teachers address students by their name, stable class composite, certain teachers are known from first year secondary school, etc.). Lecturers of undergraduate students, also due to their more disciplined behavior, are first and foremost providers of content knowledge. This stronger bond during school might strengthen students' belief that their learning, achievement and grades are very much controlled and therefore dependent on their teacher – and not so much on their own behavior (self-determination). For example, there are indications that the general self-determination of higher secondary school students with learning disabilities is attenuated when parents or teachers regularly solve problems for them, fostering dependence, instead of teaching them how to solve problems by themselves by providing training in problem-solving (Durlak, Rose, & Bursuck, 1994). Further differences concern the overall predefined structure of the educational institution, e.g. learning in school is regularly controlled (predefined schedule, homework and attendance), whereas learning at university is mainly organised by the students themselves. Wehmeyer and Palmer (2003) found that higher secondary school students with learning disabilities, who had high self-determination scores in their last school year, did better in multiple life categories 3 years later than those with lower self-determination, indicating higher general self-determination as beneficial for life after school. Similarly, Weimer (2002) argued that the (over)-structured classrooms of today lead students to depend on the teacher to provide rules for nearly everything (see chapter 5, pp. 95–99). She suggests learner-centered strategies for encouraging students to take responsibility for their learning.

In summary, university students are more likely to have higher self-determination than secondary school students. The reasons discussed may lead secondary school students to regard their learning outcome and grades rather related to their teachers 'goodwill' than to their own learning behavior. This might explain why in our sample with upper secondary school students, self-determination relates neither to science grades nor to achievement.

Conclusion

Conclusion for self-efficacy and career motivation

Career motivation and self-efficacy both tend to correlate with the science subject grades. As they also correlate with the knowledge scores obtained 6 and 12 weeks after the inquiry course, we conclude that both variables seem to be connected to ability and skills in science. Students who understand and can recall content knowledge after 6 and even 12 weeks, and who, due to their higher ability and skills, can earn higher subject grades, are more likely to consider science to be part of their career and are more convinced of their science skills and knowledge, than students with low subject grades and/or low ability to recall content knowledge. In the 2007 and 2011 study of Glynn et al., all SMQII subscales correlated significantly with college students' grades (science GPA). They concluded that higher motivated students earn better science grades. Although we would conclude the same from our data on the base of self-efficacy and career motivation, the different behavior of the self-determination variable is surprising but recurring. Further studies, like Schumm and Bogner (2016), using the SMQII with secondary school students may provide further information on these differing findings.

Contrary to Glynn et al.'s (2011) suggestion that the SMQII can be used to measure changes in motivational components, we found that this is not necessarily true for use in secondary school classes. Neither career motivation nor self-efficacy was affected by a single course – not by our 3-hour inquiry-based course, nor by any other event within the 14 weeks of observation. Students therefore seem to base answers about career motivation and self-efficacy on information and experience gathered over a longer period of time, so that single events will not influence their answers to the test items. We therefore suggest that applying the subscales of career motivation and self-efficacy only once is sufficient if the scales are to accompany a short-term intervention in secondary school, due to its rather robust nature against co-occurring events. Whether career motivation and self-efficacy can be influenced by long-term interventions or interventions aiming directly at improving these variables still needs to be tested with pupils. Due to their rather short nature, both subscales can be used in class easily by teachers to obtain an accurate measure of students' self-assessment of their general career motivation and self-efficacy.

Conclusion for self-determination

Self-determination fails to significantly correlate with science grades. Together with the finding that self-determination also fails to correlate with secondary school students' knowledge scores, we conclude that self-determination is independent from students' skills and abilities (knowledge test), or their accumulated, externally observed abilities (subject grade). To foster self-determination, simply helping them to access better test scores or subject grades would probably fail. As our results show, involving them in structured inquiry tasks helps one to increase their self-determination, perhaps because students directly needed to use their newly acquired knowledge for handling the hands-on experiments and answering questions. They therefore saw that it was up to them if they wanted to understand the topic. That the teacher steps back and is not the center of attention, as he does not provide knowledge or answers, could be the crucial part here. As inquiry-based learning may give students more autonomy, higher autonomy is thought to positively influence self-determination (Black & Deci, 2000; Palmer, 2005). Although the increase of self-determination was of short duration only, occurring directly after participation in the lesson block, we suggest that self-determination can be improved due to brief student-centered, constructivistic activities such as structured inquiry-based learning. An increase in the frequency of inquiry throughout the school year might lead to an extended increase in self-determination. However, whether short-term increases of self-determination lead to a more sustainable increase in science self-determination still needs clarification.

As the positive impact was of short duration only, students seem to judge their rating of the self-determination-items rather on events recently experienced, despite questions being formulated for their general self-determination behavior. This effect is unlikely to be an effect of translation, as all three subscales aimed at students' general opinion and only self-determination was treated differently by the students. The higher learning autonomy within our inquiry-based learning environment might be the main reason why self-determination was increased compared to conventional, teacher-centered lessons before and after the intervention, as autonomy can positively influence self-determination (Black & Deci, 2000). To summarise, we cannot conclude from the data obtained, what exactly might have influenced self-determination within the 14 weeks of observation, but we can exclude direct linkages to science subject grades and test scores and emphasise the usage of inquiry-based learning, or other forms of learning that give students more autonomy for their learning for further research on how to increase self-determination in secondary school students. We also suggest that, since self-determination can be influenced by single short events, the self-determination subscale should be used several times (before and after an intervention) to measure its impact on this variable. For science teachers, the subscale of self-determination therefore offers a tool to monitor the influence of a lesson, excursion or science day on the class's self-determination. We suggest caution with generalisations of results obtained by the self-determination subscale if it is measured just once and co-occurring events were not taken into account. Additionally, caution in interpreting results might be necessary, as item wording of the SMQIIs subscale self-determination may focus too much on effort and time investment instead of perceived control of learning.

Recommendations

We would advise caution in using the SMQII for tracking secondary school students' motivation, as its power seems limited because the subscales seem to have unequal sensitivity in the face of lesson participation. Two out of these three subscales were rated unchanged over a period of 14 weeks including lesson participation and therefore may need more focused, longer lasting or stronger feedback than from a single lesson of 3 hours like ours. The third subscale was sensitive enough to be positively influenced through class participation, but the impact was not sustainable and the relatedness to the other two subscales is questionable due to a lack of correlations. Considering self-determination to be part of the same motivation-continuum as self-efficacy and career motivation seems to us to be unjustified in the case of secondary school students. Similar findings were made by Schumm and Bogner (2016). We therefore rather limit career motivation and self-efficacy as indications of school students' science motivation.

As the change tracking in students' motivation to learn science resulted either in no changes at all (SE and C) or only in changes of short duration (SD), some caution is advised in interpreting the subscales. However, we still think that their implementation in secondary school classes is a useful tool for teachers. The subscales provide information on career motivation, self-efficacy and self-determination. The subscales of career motivation and self-efficacy can form the base for discussing why students are (not) very motivated. For example, lack of information about science job opportunities, the importance of understanding science for daily life or reasons why students perceive to lack competence in science could be discovered. Using the self-determination subscale can provide information on the mental maturity and indicate if students already recognised that their learning outcomes (test scores and grades) are dependent on them and their learning investment and not, e.g. their teachers' goodwill. Our results on self-determination indicate that constructivistic approaches, like inquiry-based learning, may foster an increase in students' self-determination.

When teachers detect reasons for low motivation for science or low self-determination, they could adapt their teaching or provide information on the problem areas mentioned above to increase science motivation or awareness of consequences of investing time and effort for learning. Increasing science motivation will likely affect students' achievement positively and eventually promote their science literacy needed for their daily life after school. It can help teachers to form literate citizens or even motivate students to opt for a career in science. Increasing students' self-determination is likely to be beneficial for their overall life after school (Wehmeyer & Palmer, 2003; Weimer, 2002). If they learn to take responsibility for their learning during school, they may recognise earlier that their own learning behavior causes their achievement and grades, which may open opportunities to use learning strategies or ask for help when they are not satisfied with their achievements.

As Thelen, criticising the 'hit-and-run' style of learning in school, has already claimed in 1975, education should not only develop individual powers but also prepare effective citizens, because students are someday 'going to manage others; interpret the world around them; make discoveries; create social, political, and economic alternatives; ferret out facts; and persuade, promote, criticize, analyze, guide, console, and teach' (p. 107). We therefore agree with Thelen (1975), who promoted the frequent use of short questionnaires by teachers to help to guide their instruction.

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References

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Freeman.

Bandura, A. (2001). Social cognitive theory: An agentic perspective. *Annual Review of Psychology*, *52*(1), 1–26.

Black, A. E., & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination theory perspective. *Science Education*, *84*(6), 740–756.

Blanchard, M. R., Southerland, S. A., Osborne, J. W., Sampson, V. D., Annetta, L. A., & Granger, E. M. (2010). Is inquiry possible in light of accountability? A quantitative comparison of the relative effectiveness of guided-inquiry and verification laboratory instruction. *Science Education*, *94*(4), 577–616.

Brickman, P., Gormally, C., Armstrong, N., & Hallar, B. (2009). Effects of inquiry-based learning on students' science literacy skills and confidence. *International Journal for the Scholarship of Teaching and Learning*, *3*(2), 1–22.

Britner, S. L., & Pajares, F. (2001). Self-efficacy beliefs motivation race and gender in middle school science. *Journal of Women and Minorities in Science and Engineering*, *7*(4), 271–285.

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching*, *43*(5), 485–499.

Britner, S. L. (2008). Motivation in high school science students: A comparison of gender differences in life, physical, and earth science classes. *Journal of Research in Science Teaching*, *45*(8), 955–970.

Bryan, R. R., Glynn, S. M., & Kittleson, J. M. (2011). Motivation, achievement, and advanced placement intent of high school students learning science. *Science Education*, *95*(6), 1049–1065.

Cavallo, A. M., Potter, W. H., & Rozman, M. (2004). Gender differences in learning constructs, shifts in learning constructs, and their relationship to course achievement in a structured inquiry, yearlong college physics course for life science majors. *School Science and Mathematics*, *104*(6), 288–300.

Crawford, B. A. (2000). Embracing the essence of inquiry: New roles for science teachers. *Journal of Research in Science Teaching*, *37*(9), 916–937.

Dunlap, J. C. (2005). Problem-based learning and self-efficacy: How a capstone course prepares students for a profession. *Educational Technology Research and Development*, *53*(1), 65–83.

Durlak, C. M., Rose, E., & Bursuck, W. D. (1994). Preparing high school students with learning disabilities for the transition to postsecondary education: Teaching the skills of self-determination. *Journal of Learning Disabilities*, *27*(1), 51–59.

Eurydice. (2011). *Science education in Europe: National policies, practices and research*. doi:10.2797/7170

Field, A. (2005). *Discovering statistics using SPSS statistics*. London: Sage.

Gibson, H. L., & Chase, C. (2002). Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. *Science Education*, *86*(5), 693–705.

Glynn, S. M., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science motivation questionnaire II: Validation with science majors and nonscience majors. *Journal of Research in Science Teaching*, *48*(10), 1159–1176.

Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2007). Nonscience majors learning science: A theoretical model of motivation. *Journal of Research in Science Teaching*, *44*(8), 1088–1107.

Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2009). Science motivation questionnaire: Construct validation with nonscience majors. *Journal of Research in Science Teaching*, *46*(2), 127–146.

Gwilliam, L. R., & Betz, N. E. (2001). Validity of measures of math-and science-related self-efficacy for African Americans and European Americans. *Journal of Career Assessment*, *9*(3), 261–281.

Jonassen, D. H. (2000). Toward a design theory of problem solving. *Educational Technology Research and Development*, *48*(4), 63–85.

Linn, M. C., Davis, E. A., & Bell, P. (Eds.). (2004). *Internet environments for science education*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Marth, M., & Bogner, F. X. (2017). How a hands-on BIONICS lesson may intervene with science motivation and technology interest. *International Journal of Learning, Teaching and Educational Research*, *16*(5), 72–89.

Meece, J. L. (1997). *Child and adolescent development for educators*. New York: McGraw-Hill.

Mertens, D. M. (2010). *Research methods in education and psychology. Integrating diversity with quantitative and qualitative approaches*. Thousand Oaks, CA: Sage.

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections* (Vol. 13). London: The Nuffield Foundation.

Pajares, F. (1996). Self-efficacy beliefs and mathematical problem-solving of gifted students. *Contemporary Educational Psychology*, *21*(4), 325–344.

Pajares, F. (2002). Gender and perceived self-efficacy in self-regulated learning. *Theory Into Practice*, *41*(2), 116–125.

Pajares, F., & Schunk, D. H. (2001). Self-beliefs and school success: Self-efficacy, self-concept, and school achievement. In R. Riding, & S. Rayner (Eds.), *Perception* (pp. 239–266). London: Ablex Publishing.

Palmer, D. (2005). A motivational view of constructivist-informed teaching. *International Journal of Science Education*, *27*(15), 1853–1881.

Patrick, H., Mantzicopoulos, P., & Samarapungavan, A. (2009). Motivation for learning science in kindergarten: Is there a gender gap and does integrated inquiry and literacy instruction make a difference. *Journal of Research in Science Teaching*, *46*(2), 166–191. DOI: 10.1002/tea.20276.

Prince, M., & Felder, R. (2007). The many faces of inductive teaching and learning. *Journal of College Science Teaching*, *36*(5), 14.

Schmid, S., & Bogner, F. X. (2015). Does inquiry-learning support long-term retention of knowledge? *International Journal of Learning, Teaching and Educational Research*, *10*(4), 1–3.

Schumm, M. F., & Bogner, F. X. (2016). Measuring adolescent science motivation. *International Journal of Science Education*, *38*(3), 434–449. DOI: 10.1080/09500693.2016.1147659.

Schunk, D. H. (1985). Self-efficacy and classroom learning. *Psychology in the Schools*, *22*(2), 208–223.

Schunk, D. H., & Meece, J. L. (2005). Self-efficacy development in adolescence. In F. Pajares, & T. Urdan (Eds.), *Self-efficacy beliefs of adolescents* (pp. 71–96). Greenwich, CT: Information Age Publishing.

Sekretariat der Ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland. (2013). *Vorgaben für die klassenbildung. Berlin: Kultusministerkonferenz.*

Stake, J. E., & Mares, K. R. (2001). Science enrichment programs for gifted high school girls and boys: Predictors of program impact on science confidence and motivation. *Journal of Research in Science Teaching*, *38*(10), 1065–1088.

Statistische Ämter des Bundes und der Länder. (2013). *Internationale bildungsindikatoren im ländervergleich*. Wiesbaden: Statistisches Bundesamt.

Thelen, H. A. (1975). The triumph of "achievement" over inquiry in education. *The Elementary School Journal*, *75*, 103–109.

Tuan, H. L., Chin, C. C., Tsai, C. C., & Cheng, S. F. (2005). Investigating the effectiveness of inquiry instruction on the motivation of different learning styles students. *International Journal of Science and Mathematics Education*, *3*(4), 541–566.

Wehmeyer, M. L., & Palmer, S. B. (2003). Adult outcomes for students with cognitive disabilities three-years after high school: The impact of self-determination. *Education and Training in Developmental Disabilities*, *38*(2), 131–144.

Weimer, M. (2002). *Learner-centered teaching: Five key changes to practice*. San Francisco, CA: John Wiley & Sons.

Wimpey, A., Wade, C., & Benson, L. (2011). Linking Pedagogy to Practice: Improving Student Motivation and Academic Performance in STEM Courses through Inquiry-Based Instruction. Presented at the 2010 National Association for Research in Science Teaching, Orlando, FL, April 3–6, 2011.

Zusho, A., Pintrich, P. R., & Coppola, B. (2003). Skill and will: The role of motivation and cognition in the learning of college chemistry. *International Journal of Science Education*, *25*, 1081–1094.