International Journal of Learning, Teaching and Educational Research
Vol. 16, No. 5, pp. 72-89, May 2017

How a Hands-on BIONICS Lesson May Intervene with Science Motivation and Technology Interest

Michaela Marth and Franz X. Bogner
ZMNU (Centre of Math & Science Education),
Department of Biology Education,
University of Bayreuth

Abstract. Science is supposed to raise and support young children's interest as early as possible, at the latest at the beginning of secondary school. Our empirical study monitored individual motivation levels towards science of 6th graders by applying established measures to 324 students (age M=12.2 years, 189 girls, 135 boys). The first empirical measure consisted of the Science Motivation Questionnaire (SMQ), the second of the Technology Questionnaire (TQ). Our lesson consisted of a student-centered outreach module about bionics within a zoological garden in combination with related exhibition. Measurement was conducted two weeks before (T0), directly after (T1) and six weeks (T2) after program participation. The factor structure of the SMQ-II we obtained showed a major difference to the published structure: our young sample couldn't differentiate between intrinsic motivation (IM) and self-efficacy (SE). Moreover, the expected two subscales merged into one which we labelled self-confidence (SC). The other subscale "grade motivation" followed the expected factor structure of the original scale. While this latter subscale was unaffected by our intervention, the sub-scale SC peaked directly after program participation, but unfortunately did not sustain this shift over a six week time period. There were no gender differences at any testing point. Science motivation correlated at a low level with technology interest but failed to correlate with social implications of technology.

Keywords science motivation; factor structure; gender issues; technology interest; bionics module

Introduction

Science and technology are omnipresent in daily life (Ardies, De Maeyer, Gijbels, & van Keulen, 2015). Therefore, a scientific understanding is needed, young people need to familiarize themselves with the increasing penetration of science and technology in our lives (DeBoer, 2000). The scientific literacy paradigm seems an appropriate framework with its potential to support individual needs, as any level of scientific literacy may affect decisions related to science (Miller, 1983). Understanding dependencies is of importance for both the societal and the individual levels (Laugksch, 2000). Scientifically literate individuals tend to feel more competent regarding technology and science in everyday life, although the social, moral and intellectual attainments may need separate attention (Laugksch, 2000). School curricula should prepare children appropriately and sufficiently (ISB, 2004). In consequence, the aim of science education must be to support scientific literacy: DeBoer (2000) declared teaching science and building scientific literacy as the most important goal to prepare best for working life as well as for most other circumstances including becoming a critical consumer of information. It also may help to better understand public discussions about science as well as potential relationships between science and technology. It is alarming that interest, attitudes and motivation of students in the scientific fields seem to drop consistently during school attendance (Osborne, Simon, & Collins, 2003).

Motivation is a well-researched issue with over 100 different definitions even 35 years ago (Kleinginna & Kleinginna, 1981). Today there is general agreement on three major issues: (i) many internal aspects contribute to motivation (psychological and phenomenological), (ii) other aspects deal with functional processes, and (iii) the comprehensive nature of motivation. Motivation in the literature is also understood as dependent on self-efficacy, on beliefs in control as well as on the capability to perform a duty, and self-responsibility building upon individual achievement potential (Pintrich & De Groot, 1990). Self-efficacy is assumed to effect academic accomplishment in various ways (Pajares, 2002). While self-regulated learning is supposed to influence motivation (Zimmerman & Schunk, 2008), its integration into teaching approaches is regarded an essential need. Although 'motivation to learn science` is defined as 'an internal state that arouses, directs, and sustains science-learning behavior', its impetus often seems to be lost during school time (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011, S.1160). Therefore, educators need to support motivation and to bring interest into classrooms again. For designing educational programs, knowledge about presumed levels of motivation may support learning and understanding science. A brief and valid assessment is welcome in any classroom. Glynn, Taasoobshirazi, & Brickman (2009) developed a 30-item Science Motivation Questionnaire (SMQ) (originally for students in college courses; Glynn, Shawn &Koballa, 2006), providing the possibility to measure science motivation of university students. A later reduction to 25-items yielded a modified SMQ-II covering five subscales: intrinsic motivation (IM), self-efficacy (SE), self-determination (SD), career motivation (CM) and grade motivation (GM) by following a well-defined theory of human learning (Albert Bandura, 1986). Schumm & Bogner (2016) first applied this SMQ-II to high school age groups. Similarly, Schmid & Bogner (2017) used three sub-scales of the SMQ-II for older secondary class students who followed an inquiry approach in an interdisciplinary lesson-unit.

Technology is another trigger in science education as it is present nearly everywhere in our daily life (Ardies et al., 2015). Young people in particular grow up in a society pervaded by social media and communication technology (O'Keeffe & Clarke-Pearson, 2011). Thus, the education sector needs to care of using that tools appropriately (Ardies, De Maeyer, & Gijbels, 2013). It is important, too, that younger students be interested in technology and science. To measure interest in technology and its social aspects, we used the revised short Technology Questionnaire of Marth & Bogner (2017a). We know from the literature that school students with positive experiences at young ages are more successful later in the technology sector (Akpınar, Yıldız, Tatar, & Ergin, 2009). Especially the transition phase from primary to secondary school is regarded as important for science and technology education as this time is one of the most crucial in the lives of children (George, 2006). Motivation for science and technology needs specific promotion to counteract its tendency to decrease during adolescence (Vedder-Weiss & Fortus, 2011). Elementary school children are often not free in their choice of science or even science related activities, as the classroom teacher often decides the content (Simpkins, Davis-Kean, & Eccles, 2006). In high school, students are able to choose science courses as well as out-of-school activities, interacting with free time options like hanging out with friends, working or doing other more interesting things (Larson & Verma, 1999). There is also a distinction between cultures and economies: Asian children tend to attend after-school activities in addition to school commitments leading to better achievement effects (Larson & Verma, 1999). This transition passage, including adolescence, is one of the most crucial periods of supporting interest in science. Larson, Wilson, Brown, Furstenberg, Jr., & Verma (2002) described that transition passage as socially versatile where the most prejudices originate regarding science and learning science. It is worth spending time on science courses and science out-of-school activities to improve the general thoughts and beliefs of young students. Teachers have to be more motivated as well, and need to make experiences more meaningful for school students (Mc Robbie, 2000). It is therefore important to bring school students into contact with technology in science with a variety of programs and educational efforts.

There are in general gender differences in science motivation (Akpınar et al., 2009). Marth & Bogner (2017a) for example showed for boys in low secondary school higher technology interest scores and more social implications of technology. This trend has also been observed with freshmen and adult teachers. Only the social implications of technology seem similar within the teacher cohorts. As science traditionally is still a male-dominated field, women in academic fields like math, science or technology may feel discriminated from the beginning until their graduation, compared to a female-dominated area like art, education or social sciences (Steele, James, & Barnett, 2002). Thus, the likelihood of choosing science careers drops as further constraints like the flexibility of jobs and the traditional role combining family and career aspirations also impact (Frome, Alfeld, Eccles, & Barber, 2006). Moreover, women choosing a science career and participating in a doctoral program may show a lower career aspiration and also a lower academic self-concept (Ülkü-Steiner, Kurtz-Costes, & Kinlaw, 2000). This trend is well-known in STEM (Science, Technology, Engineering and Math) (Blickenstaff, 2005). Despite many available jobs in this sector the number of employed women remains low (Dasgupta & Stout, 2014).

A good possibility to overcome the above shown risk might strictly connect science with technology. Bionics is a substantial research area combining the biology, technology and related sciences to find suitable solutions for the improvement of technology problems, therefore nature can act as a model for

technical advantages (Nachtigall & Wisser, 2013). Bionics might be a possibility as it combines science and technology in an innovative way. More and more inventions can be expected. The lotus-effect, for example, is one of the most famous examples with its self-cleaning mechanism due to a wax-coated surface (Neinhuis & Barthlott, 1997). A further example is the shark skin with its optimized longitudinal body axis where small parallel riblets reduce drag Oeffner & Lauder (2012), which reduces wind flow in aircraft (Bechert, Bruse, Hage, Van Der Hoeven, & Hoppe, 1997). Existing technologies may be improved or invented through the inspiration of nature. Bringing these interesting and exciting new areas of science and technology into classrooms may create interest in and motivation to learn science.
Given this background, we derived four research questions: 1) Is the SMQ-II Questionnaire suitable for younger age students? 2) Does a one-day intervention influence science motivation? 3) Are there gender differences? 4) Do motivation towards science and interest for technology interact?

Methods

Intervention bionics in the zoo

Our bionics module took five complete school lessons in a zoo (see table 1). Firstly, an instruction booklet containing the relevant material and instructions for the day ensured a similar pre-knowledge. A lesson day started with a teacher-guided unit where the general aims of the day were discussed, and an introduction to the bionics given. Familiarity with the basics of bionics and of biology and technology were assumed for all participants. Each student wrote relevant information into that book and so had a portable guide, as the rest of the day in the zoo was student-centered and teachers only gave answers if needed. Students were organized into small groups of three or four. The following student-centered module was divided into two hands-on sub modules, the Aquarium Module (=AM) and the Seminar Room Module (=SM). Both sub-modules consisted of four workstations.

Table 1: Module phases and description

phase of teaching	*description*	*students activity*	*Time (Minutes)*
pre-group phase	introduction to bionics	teacher-guided learning	25
Seminar room module	seminar room activity	hands-on	85
Aquarium module	concentrating on the living animal directly in the zoo	hands-on	85
post-group phase	exhibition „BIONICUM“	Repetition	30

In the post-group phase, the exhibition `BIONICUM` provided the option to rearrange newly acquired knowledge from the pre-group and group phases by building new cognitive structures with examples from the interactive exhibition: experiments, videos, hands-on and computer-guided learning. For instance, the rodent self-sharpening teeth effect was shown in a video as well as its technical application in self-sharpening knifes. Finally, a dancing and singing robot presented bionics directly as "human model". All interventions were guided by the same teacher and tutor in order to ensure equality of the module application for all classes.

Sample and study design

324 6th graders (age M=12.2 years, 189 girls, 135 boys) participated in a hands-on guided learning module. The students completed the Science Motivation Questionnaire-II (intrinsic motivation, self-efficacy, grade motivation) three times (see figure 1). The first measurement point was two weeks before our intervention, the second directly after participation and the third six weeks after participation. At T0 additionally the shortened Technology Questionnaire (TQ) consisting of the two subscales "interest in technology" and "social implications of technology" was completed (Marth & Bogner, 2017b).

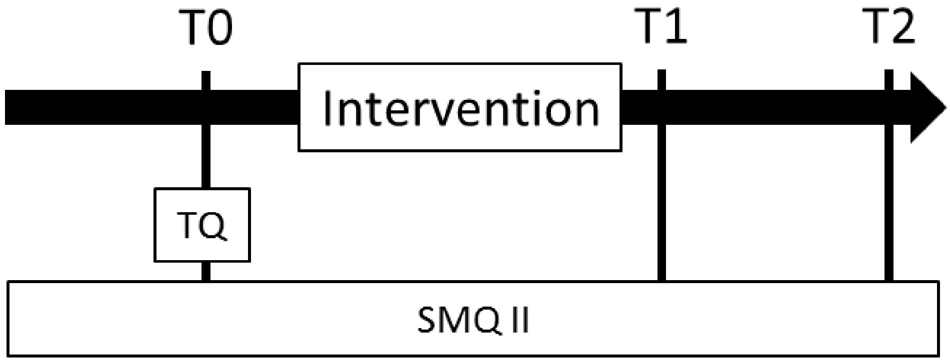

Figure 1: Schedule of questionnaire implementation

Statistical analysis

Statistical analysis was conducted using SPSS Version 23. Using the central limit theorem we used parametric testing methods.

First, we applied an explanatory factor analysis to the SMQ-II item set for visually inspect the similarity to the original scale following a principal factor analysis with oblim and varimax rotation. The suitability of our sample for factor analysis was tested using the Kaiser-Meyer-Olkin test (KMO) (Kaiser, 1970) and Bartlett's test of sphericity. The Kaiser-Guttman (Kaiser, 1960), was employed to determine the number of factors to extract.

For the analysis of the different testing points of the SMQ-II, we used for each subscale (SC = self-confidence, GM = grade motivation) a repeated measurement ANOVA based on mean scores. For pairwise comparison at the different testing points, we applied post-hoc testing with the Bonferroni correction. For the measurement of significant differences between the genders, at each testing point for each subscale we used also the repeated measurement ANOVA above. For the test-rest group we also used an ANOVA for each subscale of the SMQ II.

The Pearson Correlation coefficient was used to quantify the relationship of the SMQ II and the TQ subscale (IN = Interest, SO = social implications) mean scores.

Results

Exploratory factor analysis

We subjected the 15 items of SMQ-II (T0) to principal axis factor analysis (PAF). In contrast to the original three sub-scales IM, SE and GM, our analysis extracted two, merging the first two into a factor we labeled "self-confidence (SC)". The Kaiser-Meyer-Olkin measurement of .923 is high (Hutcheson & Sofroniou, 1999), as is Bartlett`s test of sphericity (chi-square= 2436.649; *p*=<.001) (Field, 2013). By using the Kaiser-Guttman criterion, 51.52 % of the total variance were explained. Oblique and orthogonal rotations yielded essentially the same solution. The varimax factor loadings are shown in Table 2, loadings below .35 are not shown. The percent of variance explained by "self-confidence" (SC) was 42,286%, and 9,243 % for "grade motivation" (GM).The reliability scores were reasonable for all sub-scales at all testing points, ranging from .80 to .89 (SC: T0 (αT0= .897), T1 (αT1=.868); T2 (αT2=.907); GM T0 (αT0=.844), T1 (αT1=.897), T2 (αT2=.895)).

Table 2: Factor loadings from the PAF of the pre-test values of the SMQ II (T0) (Scores under .35 are suppressed)

N= 325	F1	F2
Factor 1: Self-confidence		
1 Learning science is interesting	.727	
2 I am curious about discoveries in science	.734	
3 The science I learn is relevant to my life	.391	
4 Learning Science makes my life more meaningful	.448	
5 I enjoy learning science	.677	
6 I believe I can earn a grade of "A" in science	.673	
7 I am confident I will do well on science tests	.708	
8 I believe I can master science knowledge and skills	.815	
9 I am sure I can understand science	.752	
10 I am confident I will do well on science labs and projects	.762	
Factor 2: Grade Motivation		
11 Scoring high on science test and labs matters to me		.581
12 It is important that I get an "A" in science		.803

13 I think about the grade I will get in science	.791
14 Getting a good science grade is important to me	.904
15 I like to do better than other students on science tests	.461

The mean knowledge scores (M) and standard deviation (SD) differ significantly between the 3 different testing points for the sub-scales from the SMQ II (see Figure 2).

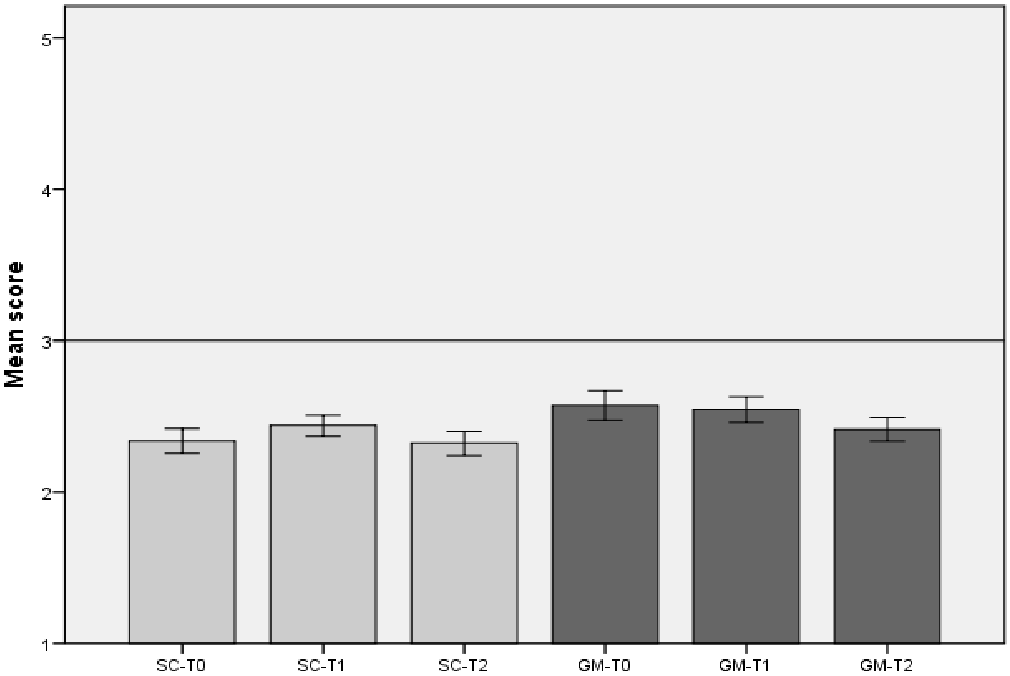

Figure 2: Mean knowledge scores of the 2 different sub-scales SC and GM to testing points T0, T1 and T2; Bars are 95% confidence intervals

The sub-scale SC showed significant differences in the repeated measurement ANOVA (F(1.969,513.930)=6.188, *p*=.002, omega=.90). For the chi-square of the sub-scale SC (2)=7.157 Mauchly`s test showed violation of the assumption of sphericity, therefore degrees of freedom were corrected by using Huynh-Feldt estimates of sphericity (epsilon=.985). The knowledge mean scores increased from T0 (M=2.36 ; SD=.751) to T1 (M=2.45 ; SD=.692) and dropped at testing point T2 (M= 2.32; SD= .772) (Figure 2). The post-hoc pair-wise comparison with the Bonferroni correction showed similar results. SC increased short-term (TO to T1; *p*=.029 and dropped again at testing point T2 (T1 to T2; *p*=.034). Testing point T0 and T2 showed no significant differences (T0 to T2; *p*=1.00).
The sub-scale SC was also analyzed for differences between the female and male participants (see Figure 3). There was no significant effect of gender (F(1.969,513.930)=.263, *p*=.766, omega=.83), indicating that the mean scores from male and female students were similar (male: T0 (M=2.43; SD=.806), T1 (M=2.55;

SD=.701); T2 (M= 2.42; SD= .765); female: T0 (M=2.28; SD=.686) to T1 (M=2.35; SD=.670), T2 (M= 2.24; SD= .772)).

For the sub-scale GM, the repeated measurement ANOVA yielded no significant differences (F(1.950,571.275)=.035, *p*=.963, omega=.90). For the chi-square of the sub-scale GM (2)=10.699 Mauchly`s test showed violation of the assumption of sphericity, therefore, degrees of freedom were corrected by using Huynh-Feldt estimates of sphericity (epsilon=.975). Knowledge mean scores stay constant from T0 (M=2.57; SD=.915) to T1 (M=2.56 ; SD=.823) and also to T2 (M=2.56 ; SD= .906) (Figure 2). The post-hoc pair-wise comparison with the Bonferroni correction showed similar results. GM stay constant short-term (TO to T1; *p*=1.00) and also to testing point T2 (T0 to T2; *p*=1.00; T1 to T2; *p*=1.00).

The sub-scale GM showed no difference between female and male participants (see Figure 3): (F (1.950,571.275)=.692, *p*=.497; omega=.80), indicating similar mean scores for male and female students (male: T0 (M=2.63; SD=.922), T1 (M=2.66; SD=.812); T2 (M= 2.60; SD= .888); female: T0 (M=2.50; SD=.905) to T1 (M=2.46; SD=.825), T2 (M= 2.52; SD= .924)).

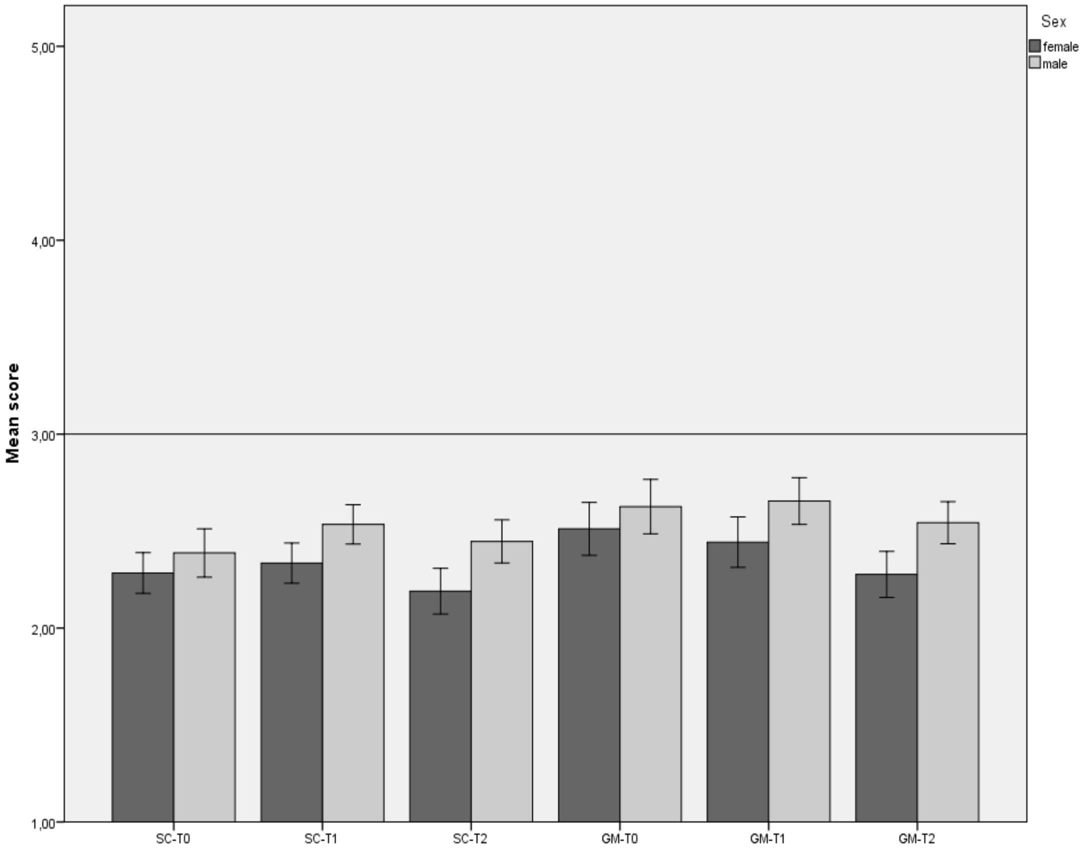

Figure 3: Mean knowledge scores of the 2 different sub-scales SC and GM to testing points T0, T1 and T2 split by gender; Bars are 95% confidence intervals

A non-participant test-retest group yielded in a repeated measurement ANOVA no difference at the different testing points in each sub-scale (SC: (F(1.883,92.250)=.223; p= .787 omega=.90; GM: (F(1.901,285.210)=.711; p= .711 omega=.90).

The correlation matrix of the SMQ-II sub-scales between each other and with the modified TQ is displayed below. The linear slope shows the interrelation among the single correlation factors.

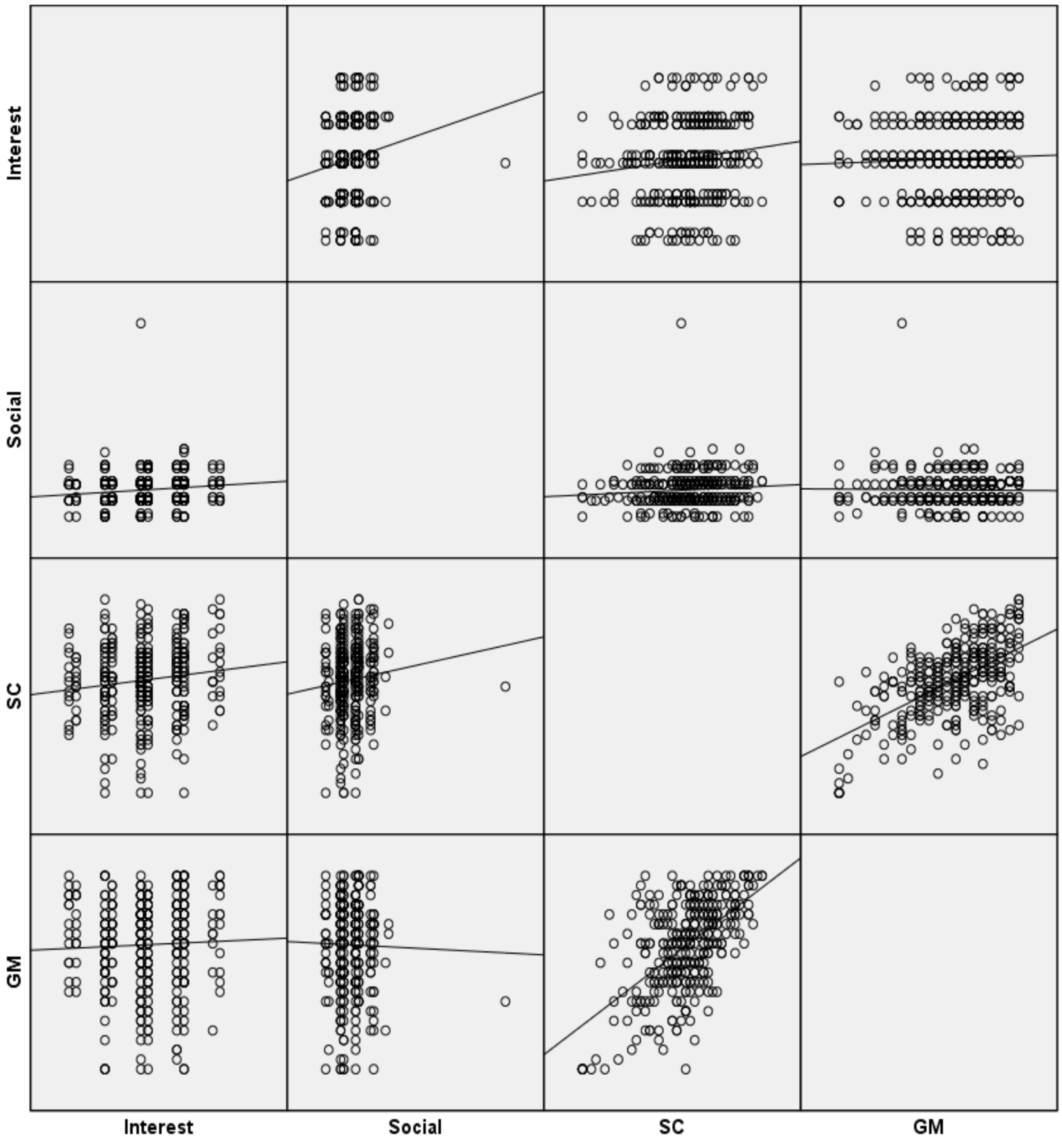

Figure 4: Pearson correlations matrix between the sub-scales SC and GM and sub-scales interest and social of the TQ: plot showing the distribution of the correlations and the positive interrelations

In addition to Figure 4 above the other testing points T1, T2 and T3 were analyzed. The intercorrelation of the SMQ II sub-scales (SC-GM) showed significant effects for all correlations (T0: r=.573 ***, p=<0.001; T1: r=.644 ***, p=<0.001; T0: r=.664 ***, p=<0.001).
The bivariate correlation of the SMQII sub-scales SC and GM with the modified TQ showed no significant differences. The sub-scale "interest" showed only a very low correlation with the sub-scale SC at testing point T0 (p=.024; r=.124; r^2=

.015). The sub-scale GM shows no significant correlation either for interest or for social.

Discussion

Science motivation of 6th graders seems to originate in different concepts compared to adolescent or adult subjects: Career-motivation and self-determination still seem far away from reality for 6th graders compared to older samples (Schumm & Bogner, 2016). The "umbrella" term may not need three sub-scales to explain its meaning (intrinsic-motivation, self-efficacy and grade motivation), since younger subjects seem to combine two to form single one: the "umbrella" factor structure for the 10 item-set (intrinsic motivation and self-efficacy) in our younger age-group differed from the earlier reported older structure (freshmen, 10th graders). Apparently the young do not discriminate between intrinsic motivation and self-efficacy. This was an unexpected result as no previous studies have suggested this pattern (Glynn et al., 2011).

Even Ryan & Deci (2000) had built upon self-determination and explained this with the importance of humans' development of personality. The original factor analysis was obtained from university students and not for younger participants as in our study. This difference may present the largest effect in the disparity with Glynn et al. (2011). This dependency might be the cause of the merging of intrinsic motivation and self-efficacy. Pintrich & De Groot (1990) have reported self-efficacy and intrinsic values as positively supporting cognitive performance. Also Zimmerman & Kitsantas (1999) reported a high correlation between self-efficacy and school students' intrinsic interest. We labeled this "umbrella" of intrinsic motivation and self-efficacy as "self-confidence" (SC).

"Confidence in one's abilities generally enhances motivation, making it a valuable asset for individuals with imperfect willpower" (Benabou & Tirole, 2002 p.871). Philosophers, educators and psychologists see self-concept as the main root of motivation, emotion and social influence; and self-confidence in skills and efficacy may help to increase motivation for different ventures (Benabou & Tirole, 2002). Kleitman & Stankov (2007) reported self-confidence to be a solid predictor of performance accurateness. It's the key to good performance and the power of endurance in different circumstances to work hard and believe in one's skills, to win a medal, for example, or perform on stage, be accepted by college, write a great book, do innovative research, set up a company, reduce weight, find a mate, and so forth (Benabou & Tirole, 2002). For us, self-confidence may trigger the ability to reach goals in science and increase self-efficacy beliefs and intrinsic motivation. The connection between self-confidence and motivation is described by Ryan & Deci (2000) who postulated intrinsic motivation and well-being as needs different psychological requirements namely competence, autonomy and relatedness. These components are the key to motivation and achieving goals.

Bandura (1977) pointed to the importance of self-efficacy for reaching a goal and how long motivation needs to last in order to achieve a target. School students may not have belief in self-efficacy in the context of science, as science is not included in primary school syllabi. As self-efficacy is defined as "people's beliefs about their capabilities to produce effects" (Bandura, 1994 p.71), it is largely the perception of the impact of someone's action that seems affected. Self-efficacy is one of the most important predictors of motivation and success in learning science: as Zimmerman (2000) saw it as basis for achievement resources depending of what the self-efficacy beliefs should measure. In our case, the measurement focus is science motivation, but school students couldn't express self-efficacy belief for motivation for school careers without knowledge of science. Bandura (1997) pointed out that students with high self-efficacy beliefs show more efforts in challenging a task and work consistently, harder and with greater persistence.

The self-determination theory of Deci & Ryan (1985) differentiated types of motivation, distinguishing between intrinsic and extrinsic motivation: intrinsic motivation is doing something with an inherent will, and extrinsic motivation has to do with goal oriented actions driven by external circumstances. The first may exist in every human, but not every person is intrinsically motivated towards similar tasks or fields (Ryan & Deci, 2000). However, intrinsic and extrinsic motivations belong together: Lin, McKeachie, & Kimm (2001) described intrinsic motivation as linked with better grades as highly extrinsic motivated students do. Therefore, educators should regard not only knowledge as the main educational goal, but also see lifelong learning as an enhancing variable supporting perception and motivational sites to better learn science (Vedder-Weiss & Fortus, 2011).

Sturm & Bogner (2008) for example used the "Intrinsic Motivation Inventory" (IMI) to demonstrate that a student-centered approach is more internally motivating than a traditional school setting. Gerstner & Bogner (2010) on the contrary found no link between motivational aspects and a traditional or student-centered approach. Another study of hands-on learning as opposed to learning in normal school settings showed more well-being and more self-determination in the former (Schaal & Bogner, 2005). The sub-scale "interest and enjoyment" of the IMI showed positive relations to the attitudes towards a cooperative learning setting (Geier & Bogner, 2011). In an outreach laboratory unit, Goldschmidt & Bogner (2015) found higher achievements scores for short- and long-term knowledge for higher motivated participants. In a student-centered learning study of the risks of smoking, Hedler & Bogner (2013) reported a creative learning environment as increasing autonomous motivation and decreasing controlled motivation. Therefore, the self-confidence towards science may provide the possibility to catch someone's interest again and focus the main features of science. In sum, the connection between self-efficacy and intrinsic motivation may offer a good chance for young secondary school students to build the self-confidence in science.

For promotion of science motivation with a one day learning program, a learning intervention might improve the science motivation with respect to self-confidence, as the significant increase after our intervention showed. This is quite in line with Brickman, Gormally, Armstrong, & Hallar (2009) where an increase in self-confidence after an inquiry lab course was reported. In our study in a zoological garden with living animals student-centered learning environments and hands-on material seem to supply an optimal way to increase knowledge (Mayer, 2004). Hands-on learning not only promotes knowledge, but it also effectively supported motivation and interest (Poudel et al., 2005). This conclusion is supported by a meta-analysis of 65 studies where cooperative learning was shown to generate better cognitive achievement and attitudes (Kyndt et al., 2013). Nevertheless, the self-confidence shift we initially observed was not maintained six weeks after participation. Repeated interventions, or especially promoted science related courses and out-of-school activities might keep shifts consistent over time. Science activity participation for example has been shown to predict science perceptions in high school (Simpkins et al., 2006). Parental support provided also needs attention, as parents pass their own attitudes and feelings about science and math on to their children (Jacobs & Bleeker, 2004). The STEM field meets with low interest and motivation in the view of the general public. Especially during the secondary school it dropped enormously, one reason being teacher-student interactions (Kiemer, Gröschner, Pehmer, & Seidel, 2015).

Grade motivation was irrelevant to our intervention as a program day in a zoo earns no grades. One point of such a program is to enjoy the intervention day in the zoo without the anxiety of grade or judgment from the classroom teachers. Terry, Mills, & Sollosy (2008), however, showed students to be more motivated when they do earning grades in such a context. Ryan & Deci (2000) described for extrinsic motivation as referring, making something just because of an expected result. Nevertheless, we generally need to mention that our low scores for self-confidence and grade motivation might be explained by in the age of our participants: young students may show low self-confidence and grade motivation for science because their science education started only one year before the intervention. Schumm & Bogner (2016) worked with cohorts four years older than our sample) and reported much higher science motivation both intrinsically and extrinsically. Similarly, Glynn et al. (2011) reported much higher science motivation for university students. Taken together, self-confidence could be influenced in the short-term and grade motivation unaffected by our intervention.

The lack of gender differences finds support in other studies. Zeyer (2010) or Zeyer & Wolf (2010) reported similar results, concluding that motivation does not matter for learning science by gender. Conradty & Bogner (2008) for example showed for 8th grade girls higher intrinsic motivation scores in scientific topics while Schumm & Bogner (2016) and Obrentz (2012) reported lower self-efficacy scores for girls. Glynn et al. (2011) worked with university freshmen, Obrentz (2012) with college freshmen and Schumm & Bogner (2016) with 10th graders. Our 6th graders represent a transition between childhood and early adolescence with all the biological, physical and metacognitive changes in this stage of life. Differences in lack of self-confidence may suggest this. Similarly, Wigfield (1996) reported for primary school children equal confidence scores in math and science, while middle school children already showed a gender gap. In the literature, a gender difference with lower science motivation scores is expected (e.g., Obrentz 2012; Glynn et al. (2009)) where in first case girls show less self-efficacy and trust in science. As most studies worked with high school or university subjects, our reported lack of a gender gap may convince.

Relationships between technology and science seem complex: Science motivation with its sub-scales self-confidence and grade motivation correlated significantly, in agreement with Glynn et al. (2011) when the different factor structure is not taken into account. Moreover, Glynn et al. (2011), Obrentz (2012) and Goldschmidt & Bogner (2015) have reported a dependence of science motivation on achievement scores. Schumm & Bogner (2016) found small correlations between the motivation of self-determination and the sub-scales of the big-5 “consciousness” and “neuroticism”. Our small correlation between “self-confidence” and “interest in technology” supposes to connect both variables anyway as technology and science are related fields especially in the bionics field (Bannasch, 2009). Mistler-Jackson & Songer (2000) also reported a motivational influence in a technology-driven intervention. Similarly, scientists’ and public thoughts may exert a big influence on the motivation of science and technology (Martín-Sempere, Garzon-Garcia, & Rey-Rocha, 2008). Also, Aikenhead & Ryan (1992) concluded that science included a technology site in our “Science-Technology-Society” as both are belonging together and approximate each other. Fields like bionics build up an appropriate interface as teaching science and technology should be not separated in school classes. Teachers and educators should try also to combine these fields to enhance students’ beliefs and knowledge and to build new cognitive structures supporting scientific literacy and technological know-how.

Conclusion

Knowledge about science motivation offers useful and consistent information in a classroom. Extrinsic motivation (including the motivation to earn good grades) seems to be one of the biggest predictors of school success, a factor which outreach interventions cannot exploit since they do not give grades. Nevertheless, outreach experience offers a chance to raise the general motivation for science. Intrinsic motivation as part of the self-confidence concept in combination with self-efficacy can be exploited with appropriate activities such as field-days, extracurricular programs or out-of-school courses. Innovative issues such as bionics may interact with the variables described (at least our study supported this). When students are interested in STEM in school they were able to take it home and persuade parents or friends of the need for science in modern society. Even if they only inspire themselves, school needs to incorporate STEM education in education of the young generation. Our study is another option to bring science into the school context especially in the students’ minds, but it may represent another approach to supporting STEM.

Acknowledgements

We are grateful to the ‘BIONICUM` for assistance as we are to all schools, teachers and students for participation. Similarly, we thank the Bavarian Ministry of Education for permitting the study within schools (X.7-BO4106/453/9, 03.02.2015). Financial support was granted by the CREATIONS Project (European Union Grant Agreement, No. 665917), by the University of Bayreuth as well as by the LfU (Landesamt für Umwelt).

References

Aikenhead, G. S., & Ryan, A. G. (1992). The Development of a New Instrument: “Views on Science- Technology-Society” (VOSTS). Science Education, 76(5), 477–491. http://doi.org/10.1002/sce.3730760503

Akpınar, E., Yıldız, E., Tatar, N., & Ergin, Ö. (2009). Students' attitudes toward science and technology: an investigation of gender, grade level, and academic achievement. Procedia - Social and Behavioral Sciences, 1(1), 2804–2808. http://doi.org/10.1016/j.sbspro.2009.01.498

Ardies, J., De Maeyer, S., & David Gijbels. (2013). Reconstructing the Pupils Attitude Towards Technology-survey. Design and Technology Education: An International Journal, 18(2006), 8–19. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=13601431&AN=91702283&h=dt+AM1P/ZeQYPMqTzjcxpE+PJ1NYwwdO5PJwmocqbfl5B1IUkxSzSZjCguQ6Akp0fxd+6ZjD+GDpTJy5+QQBMw==&crl=c

Ardies, J., De Maeyer, S., Gijbels, D., & van Keulen, H. (2015). Students attitudes towards technology. International Journal of Technology and Design Education, 25(1), 43–65. http://doi.org/10.1007/s10798-014-9268-x

Bandura, A. (1977). Toward a unifying theory of behavioral change. Psychological Review, 84(2), 191–215. http://doi.org/10.1037/0033-295X.84.2.191

Bandura, A. (1986). Social Foundations of Thought and Action : a Social Cognitive Theory. Englewood Cliffs, N.J: Prentice-Hall, 1986. xiii, 617 pp. http://doi.org/http://dx.doi.org/10.1037/13273-005

Bandura, A. (1994). Self-Efficacy. Encyclopedia of Human Behavio, 4, 71–81. http://doi.org/10.1002/9780470479216.corpsy0836

Bandura, A. (1997). Self-efficacy: The Exercise of Control. Encyclopedia of Human Behavior, 4, 71–81. http://doi.org/10.1002/9780470479216.corpsy0836

Bannasch, R. (2009). Bionics. In Technology Guide (pp. 178–183). Retrieved from http://dx.doi.org/10.1007/978-3-540-88546-7_35

Bechert, D. W., Bruse, M., Hage, W., Van Der Hoeven, J. G. T., & Hoppe, G. (1997). Experiments on drag-reducing surfaces and their optimization with an adjustable geometry. Journal of Fluid Mechanics, 338, 59–87. http://doi.org/10.1017/S0022112096004673

Benabou, R., & Tirole, J. (2002). Self-confidence and personal motivation. Quarterly Journal of Economics, 3(1), 871–914. http://doi.org/10.1007/s13398-014-0173-7.2

Blickenstaff, J. C. (2005). Women and science careers: leaky pipeline or gender filter? Gender and Education, 17(4), 369–386. http://doi.org/10.1080/09540250500145072

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. http://doi.org/10.1016/j.iheduc.2009.11.003

Conradty, C., & Bogner, F. (2008). vs. textbook: Effects on motivation and gain in knowledgeComputer. Proceedings of the 7th European Conference on E-Learning, ECEL 2008, 1(August), 231–238. http://doi.org/10.3390/educsci6030029

Dasgupta, N., & Stout, J. G. (2014). Girls and Women in Science, Technology, Engineering, and Mathematics: STEMing the Tide and Broadening Participation in STEM Careers. Policy Insights from the Behavioral and Brain Sciences, 1(1), 21–29. http://doi.org/10.1177/2372732214549471

DeBoer, G. E. (2000). Scientific Literacy : Another Look at Its Historical and Contemporary Meanings and Its Relationship to Science Education Reform. Journal of Research in Science Teaching, 37(6), 582–601. http://doi.org/10.1002/1098-2736(200008)37

Deci, E. L., & Ryan, R. M. (1985). Intrinsic motivation and self-determination in human behavior. Journal of Chemical Information and Modeling (Vol. 53). http://doi.org/10.1017/CBO9781107415324.004

Field, A. (2013). Andy Field - Discovering Statistics Using SPSS. (M. Carmichael, Ed.) (4th ed.). London: Sage Publications. http://doi.org/10.1111/j.1365-2648.2007.04270_1.x

Frome, P. M., Alfeld, C. J., Eccles, J. S., & Barber, B. L. (2006). Why don't they want a male-dominated job? An investigation of young women who changed their occupational aspirations. Educational Research and Evaluation, 12(4), 359–372. http://doi.org/10.1080/13803610600765786

Geier, C., & Bogner, F. X. (2011). Learning at workstations . Students ' satisfaction , attitudes towards cooperative learning and intrinsic motivation. Journal for Educational Research Online, 3(2), 3–14.

George, R. (2006). A Cross - domain Analysis of Change in Students' Attitudes toward Science and Attitudes about the Utility of Science. International Journal of Science Education, 28(6), 571–589. http://doi.org/10.1080/09500690500338755

Gerstner, S., & Bogner, F. X. (2010). Cognitive Achievement and Motivation in Hands-on and Teacher-Centred Science Classes: Does an additional hands-on consolidation phase (concept mapping) optimise cognitive learning at work stations? International Journal of Science Education, 32(7), 849–870. http://doi.org/10.1080/09500690902803604

Glynn, Shawn M., Koballa Thomas R., J. (2006). Motivation to learn in college science. Retrieved from https://coe.uga.edu/assets/files/mse/smqii-10-glynn-koballa-2006.pdf

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. http://doi.org/10.1002/tea.20442

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. http://doi.org/10.1002/tea.20267

Goldschmidt, M., & Bogner, F. X. (2015). Learning About Genetic Engineering in an Outreach Laboratory: Influence of Motivation and Gender on Students' Cognitive Achievement. International Journal of Science Education, Part B, 6(2), 166–187. http://doi.org/10.1080/21548455.2015.1031293

Hedler, C. S., & Bogner, F. X. (2013). Creative Learning Setting: Autonomous Self-Regulatory Support as Smoking Prevention. Creative Education, 4(2), 154–159. http://doi.org/10.4236/ce.2013.42022

Hutcheson, G., & Sofroniou, N. (1999). The multivariate social scientist. Introductory statistics using generalized linear models. http://doi.org/10.4135/9780857028075

Institute ISB. (2004). Curriculum 6th grade. Retrieved from https://www.isb.bayern.de/gymnasium/lehrplan/gymnasium/fachprofil-ebene-2/natur-und-technik-/325/

Jacobs, J. E., & Bleeker, M. M. (2004). Girls' and boys' developing interests in math and science: do parents matter? New Directions for Child and Adolescent Development, 2004(106), 5–21. http://doi.org/10.1002/cd.113

Kaiser, H. F. (1960). Consequently Perhaps. Measurement, XX(1), 141–151.

Kaiser, H. F. (1970). A second generation little jiffy. Psychometrika, 35(4), 401–415.

Kiemer, K., Gröschner, A., Pehmer, A. K., & Seidel, T. (2015). Effects of a classroom discourse intervention on teachers' practice and students' motivation to learn mathematics and science. Learning and Instruction, 35, 94–103. http://doi.org/10.1016/j.learninstruc.2014.10.003

Kleinginna, P. R., & Kleinginna, A. M. (1981). A categorized list of motivation definitions, with a suggestion for a consensual definition. Motivation and Emotion, 5(3), 263–291. http://doi.org/10.1007/BF00993889

Kleitman, S., & Stankov, L. (2007). Self-confidence and metacognitive processes. Learning and Individual Differences, 17(2), 161–173. http://doi.org/10.1016/j.lindif.2007.03.004

Kyndt, E., Raes, E., Lismont, B., Timmers, F., Cascallar, E., & Dochy, F. (2013). A meta-analysis of the effects of face-to-face cooperative learning. Do recent studies falsify or verify earlier findings? Educational Research Review, 10, 133–149. http://doi.org/10.1016/j.edurev.2013.02.002

Larson, R. W., & Verma, S. (1999). How children and adolescents spend time across the world: Work, play, and developmental opportunities. Psychological Bulletin, 125(6), 701–736. http://doi.org/10.1037/0033-2909.125.6.701

Larson, R. W., Wilson, S., Brown, B. B., Furstenberg, Jr., F. F., & Verma, S. (2002). Changes in adolescents' interpersonal experiences: Are they being prepared for adult relationships in the twenty-first century? Journal of Research on Adolescence, 12(1), 31–68. http://doi.org/10.1111/1532-7795.00024

Laugksch, R. (2000). Scientific literacy: A conceptual overview. Science Education, 84, 71–94. http://doi.org/10.1002/(SICI)1098-237X(200001)84:1<71::AID-SCE6>3.0.CO;2-C

Lin, Y. G., McKeachie, W. J., & Kim, Y. C. (2001). College student intrinsic and/or extrinsic motivation and learning. Learning and Individual Differences. http://doi.org/10.1016/S1041-6080(02)00092-4

Marth, M. & Bogner, F. X. (2017a). Monitoring a gender gap in interest and social implications of technology in different age groups: a revision of the Technology Questionnaire. Under Submission.

Marth, M. & Bogner, F. X. (2017b). Does the issue of bionics within a student-centered, zoological garden module generate long-term knowledge? Under Submission.

Martin-Sempere, M. J., Garzon-Garcia, B., & Rey-Rocha, J. (2008). Scientists' motivation to communicate science and technology to the public: surveying participants at the Madrid Science Fair. Public Understanding of Science, 17(3), 349–367. http://doi.org/10.1177/0963662506067660

Mayer, R. E. (2004). Should there be a three-strike rule against pure discovery learning? American Psychologist, 59(1), 14–19. http://doi.org/10.1037/0003-066X.59.1.14

Mc Robbie, J. C. ; (2000). Preservice primary teachers' thinking about technology and technology education. International Journal of Technology and Design Education, 10(d), 81–101.

Miller, J. D. (1983). Scientific Literacy: A Conceptual and Empirical Review. Daedalus (Boston), 112(2), 29–48. Retrieved from http://www.jstor.org/stable/20024852

Mistler-Jackson, M., & Songer, N. B. (2000). Student Motivation and Internet Technology : Are Students Empowered to Learn Science ? Journal of Research in Science Teaching, 37(5), 459–479.

Nachtigall, W., & Wisser, A. (2013). Bionik in Beispielen: 250 illustrierte Ansätze. Springer-Verlag. http://doi.org/10.1017/CBO9781107415324.004

Neinhuis, C., & Barthlott, W. (1997). Characterization and Distribution of Water-repellent, Self-cleaning Plant Surfaces. Annals of Botany, 79(6), 667–677. http://doi.org/10.1006/anbo.1997.0400

O'Keeffe, G. S., & Clarke-Pearson, K. (2011). The Impact of Social Media on Children, Adolescents, and Families. PEDIATRICS, 127(4), 800–804. http://doi.org/10.1542/peds.2011-0054

Obrentz, S. (2012). Predictors of Science Success: The Impact of Motivation and Learning Strategies on College Chemistry Performance. Educational Psychology and Special Education Dissertations.

Oeffner, J., & Lauder, G. V. (2012). The hydrodynamic function of shark skin and two biomimetic applications. Journal of Experimental Biology, 215(5), 785–795. http://doi.org/10.1242/jeb.063040

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. International Journal of Science Education, 25(9), 1049–1079. http://doi.org/10.1080/0950069032000032199

Pajares, F. (2002). Gender and perceived self-efficacy in self-regulated learning. Theory Into Practice, 41(2), 116–125. http://doi.org/10.1207/s15430421tip4102_8

Pintrich, P. R., & De Groot, E. V. (1990). Motivational and Self-Regulated Learning Components of Classroom Academic Performance. Journal of Educational Psychology, 82(1), 33–40. http://doi.org/10.1037/0022-0663.82.1.33

Poudel, D. D., Vincent, L. M., Anzalone, C., Huner, J., Wollard, D., Clement, T., … Blakewood, G. (2005). Hands-On Activities and Challenge Tests in Agricultural and Environmental Education. Journal of Environmental Education, 36(4), 10–22.

Ryan, R., & Deci, E. (2000). Self-determination theory and the facilitation of intrinsic motivation. American Psychologist, 55(1), 68–78. http://doi.org/10.1037/0003-066X.55.1.68

Schaal, S., & Bogner, F. X. (2005). Human visual perception - learning at workstations. Journal of Biological Education, 40(1), 32–37. http://doi.org/10.1080/00219266.2005.9656006

Schmid, S., &Bogner, F.X. (2017). How an inquiry-based lesson in upper secondary classrooms intervene with science motivation. Under Submission.

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

Simpkins, S. D., Davis-Kean, P. E., & Eccles, J. S. (2006). Math and Science Motivation: A Longitudinal Examination of the Links Between Choices and Beliefs. Developmental Psychology, 42(1), 70–83. http://doi.org/10.1037/0012-1649.42.1.70

Steele, J., James, J. B., & Barnett, R. C. (2002). Learning in a Man'S World: Examining the Perceptions of Undergraduate Women in Male-Dominated Academic Areas. Psychology of Women Quarterly, 26(1), 46–50. http://doi.org/10.1111/1471-6402.00042

Sturm, H., & Bogner, F. X. (2008). Student- oriented versus Teacher- centred: The effect of learning at workstations about birds and bird flight on cognitive achievement and motivation. International Journal of Science Education, 30(7), 941–959. http://doi.org/10.1080/09500690701313995

Terry, N., Mills, L., & Sollosy, M. (2008). Student Grade Motivation as a Determinant of Performance on the Business Major Field ETS Exam. Journal of College Teaching & Learning, 5(7), 27–32. Retrieved from https://proxy.library.upenn.edu/login?url=http://search.proquest.com/docview/742882889?accountid=14707%5Cnhttp://elinks.library.upenn.edu/?ctx_ver=Z39.88-2004&ctx_enc=info:ofi/enc:UTF-8&rfr_id=info:sid/ProQ%3Aericshell&rft_val_fmt=info:ofi/fmt:kev:mtx:jou

Ülkü-Steiner, B., Kurtz-Costes, B., & Kinlaw, C. R. (2000). Doctoral student experiences in gender-balanced and male-dominated graduate programs. Journal of Educational Psychology, 92(2), 296–307. http://doi.org/10.1037/0022-0663.92.2.296

Vedder-Weiss, D., & Fortus, D. (2011). Adolescents' Declining motivation to learn science: Inevitable or not? Journal of Research in Science Teaching, 48(2), 199–216. http://doi.org/10.1002/tea.20398

Wigfield, A. (1996). Development between the ages of 11 and 25. Handbook of Educational Psychology, 148.

Zeyer, A. (2010). Motivation to Learn Science and Cognitive Style. Eurasia Journal of Mathematics Science & Technology Education, 6(2), 121–128.

Zeyer, A., & Wolf, S. (2010). Is There a Relationship between Brain Type, Sex and Motivation to Learn Science? International Journal of Science Education, 32(16), 2217–2233. http://doi.org/10.1080/09500690903585184

Zimmerman, B. J. (2000). Self-efficacy: An essential motive to learn. Contemporary Educational Psychology, 25(March), 82–91. http://doi.org/10.1006/ceps.1999.1016

Zimmerman, B. J., & Kitsantas, A. (1997). Developmental phases in self-regulation: Shifting from process to outcome goals. Journal of Educational Psychology... Journal of Educational Psychology, 89(1), 29–36. http://doi.org/10.1037/0022-0663.91.2.241

Zimmerman, B. J., & Schunk, D. H. (2008). Motivation: An essential dimension of self-regulated learning. Motivation and Self-Regulated Learning: Theory, Research, and Applications, 1–30. http://doi.org/10.4324/9780203831076