

Investigating the differences between girls and boys regarding the factors of frustration, boredom and insecurity they experience during science lessons

Claas Wegner, Friederike Strehlke, Phillip Weber

Claas.Wegner@Uni-Bielefeld.de, Friederike.Strehlke@Uni-Bielefeld.de, Phillip.Weber@gmx.de

Department for Didactics of Biology, Bielefeld University, Germany

Abstract. Science, technology, engineering and mathematics (STEM) are subjects comprising knowledge whose schooling is essential for every country striving after long-term economic success. Despite the already existing shortage of skilled labour within the mathematic-technical-scientific professional field, men still dominate the respective subjects and jobs. The loss of female talent as a consequence of insufficient support is inexcusable from both an economic and social point of view. This is why affirmative action should be taken during schooling years in order to prevent girls from turning their backs on STEM subjects. Bielefeld University's coeducational science project 'Kolumbus-Kids' is a programme to support gifted students in general, and especially girls. This article presents both the project and a recent study investigating how girls show differences from boys when it comes to experiencing frustration, boredom and insecurity during science lessons. These emotions highly influence a person's activation, interest and motivation and are the point of intersection for cognitive processes which makes it important to deal with them sensitively. On the basis of theoretical background information on gender related differences, the project is designed to support gifted children and girls when it comes to STEM subjects. As found in this article, the underrepresentation of women in STEM-related university classes is a problem that has to be solved not only because of the skilled labour shortage. The study shows that specifically designed tutoring projects like 'Kolumbus-Kids' contribute highly to this solution. They are able to ignite and keep the interest in STEM-related subjects alive and they also lower frustration, boredom and insecurity in the same regard. One of the most important prerequisites for success is to know the girls' interests and what the possible problems are in order to better support them.

Keywords: STEM subjects, science project, coeducation, gender differences

Introduction

STEM is an acronym referring to the academic disciplines of science, technology, engineering and mathematics (Gonzales & Kuenzi, 2012). These subjects comprise knowledge whose schooling is essential for every country striving after long-term economic success as future engineers have to be trained in these areas from a young age. Despite an already existing shortage of skilled labour within the mathematic-technical-scientific professional field, men still dominate the respective jobs (BFBE, 2013). This imbalance is not caused by lower intellectual abilities of the latter, though (Dietzold, 2003). Furthermore, scientists expect a shortage of 330,000 university graduates by 2013 in Germany alone, whereof 70,000 would be needed in sciences and 85,000 in engineering (BFBE, 2013). This shows that the loss of female talent because of insufficient support is inexcusable from an economic point of view. Although there are already corresponding programs that aim at supporting female students, gender related differences regarding STEM still exist. Apart from economic problems arising from not using females to reduce the skilled worker

shortage, it handicaps women when it comes to the average income, career prospects or the possibilities of codetermination and development within companies (Stöger, Heilemann & Ziegler, 2012). However, the extent of women's participation varies within the STEM subjects when it comes to choosing a field of study, a job or an industry (Anger et al., 2013). Whereas females make up for around 70% of students doing engineering courses that deal with textile and clothes or pharmacy, their share goes down to around 50% in biology-related classes and diminishes to 10% in fields dealing with metal and electrics (Anger et al., 2013).

In Germany, the government initiated several projects to support children in general and teamed up with 90 partners from politics, economy, science and media with the goal of further advancing such projects (Faulstich-Wieland, 2004). These programs start as early as kindergarten and thus have good chances of enthusing children; hence reducing the skilled worker shortage in STEM jobs. However, these programs show systemic errors like the absence of an extensive and continuous network of tutoring programs. This might prove a problem as individual projects often have low and short-term effects on the children's interests, thus failing to improve the overall situation in the end (Stöger et al., 2012). Bielefeld University's project 'Kolumbus-Kids' tries to build upon such criticism and to achieve the goals regarding the support of girls in STEM subjects that were depicted above. In the following sections, the project will be presented as well as different emotional characteristics which affect students' interest and motivation. In order to further improve the project and the tutoring of gifted children, Bielefeld University carried out a study aiming at investigating how girls are different from boys when it comes to experiencing frustration, boredom and insecurity during science lessons. These emotions were chosen as they influence a person's activation, interest and motivation and are the point of intersection for cognitive processes (Hascher, 2005). In the course of this article, the study methodology, study process and the results will be discussed.

The Science Project 'Kolumbus-Kids'

Big classes and the students' heterogeneity challenge teachers to satisfy the individuals' specific needs. Especially the gifted are often unchallenged, which can turn them into underachievers or disruptors in the classroom. This is why Bielefeld University established the project 'Kolumbus-Kids' in 2006. Since then, it has been promoting gifted learners between ages nine and twelve. Selected students of regional schools are invited to participate in interesting sessions dealing with biological problems and phenomena at university. These classes are designed and held by university students planning to become teachers. So far, this project is a unique concept in Germany in terms of Biology Didactics aiming at an adequate support of students gifted in natural sciences. Besides, the project is beneficial for the university students as they learn about teaching methodology and diagnostics for giftedness in a theoretical seminar, followed by a practical course where they plan and give classes in the context of the project (Wegner & Minnaert, 2012; Wegner et al., 2013; Wegner et al., 2014). The project uses the National Association for Gifted Children's understanding of the term and defines gifted individuals as those who demonstrate outstanding levels of aptitude or competence or achievement in the top 10% in one or more domains. Domains generally include any structured area of activity with both its own symbol system, for instance mathematics, music or language, and set of sensor motor skills, like painting, dance or sports (NAGC, 2013). This means gifted children have the potential to perform at a level significantly beyond what might be expected from their age-peers in any area of human ability.

Every project course takes place once a week over the course of a full school year. This enables the project's teachers to influence the students' motivation and interest in the long-term. The lessons deal with topics from physics, chemistry and biology that are not taught at school, thus broadening the students' horizon and giving them an advantage in future learning environments. It furthermore makes sure students are neither bored because of material that is already known to them nor in school when topics are repeated in later years. The most important thing about the project's lessons is that they have to be largely practical. Being a coeducational project, girls and boys work together in small groups. This makes for an interesting, productive learning environment as the gender specific characteristics often complement each other. Meanwhile, teachers try to give as much positive feedback as possible in order to make the children feel competent and to raise their self-esteem regarding science (Wegner et al., 2013).

Taking part in 'Kolumbus-Kids' is possible for students from 30 primary and secondary schools in the larger area around the city of Bielefeld in North Rhine-Westphalia, Germany. The children are recommended by their teachers before doing an aptitude test which is the essential requirement for participating. Whereas girls compared to boys usually lose interest and self-esteem in mathematics more after primary school, this is not the case in biology (Hahn, 2010). This is why 'Kolumbus-Kids' uses biological topics as a starting point from which topics related to other sciences can be introduced. Furthermore, the project uses new media and experiments, live animals and interactive Smart® Boards to make the lessons more interesting (Wegner et al., 2014). This is important as children, and especially girls, are rather reached by information that is presented in attractive ways which directly appeal to the senses (Gramm, Bohne & Stephan, 1992). In addition, the classes take place in the university's laboratories, environmental chambers and a big sea water facility specifically built for the project. This provides the students with the possibility to make first hand experiences, thus improving their abilities to think scientifically (Gramm et al., 1992).

Theoretical Background: Coeducation as a problem-solving approach

Toglia (2013) investigated the most influencing factors for women's choices regarding fields of study or jobs. His results show these are socio-economic status, their parents' expectations, jobs and educational level and the influence of respective advice centres. To improve the situation regarding STEM-related jobs, there are several strategies available, starting at basic principles of treating both genders equally in school and further education, special praise for women working in unusual fields and raising their self-esteem. The influencing factors described by Toglia (2013) emphasise the young women's familial environment, making it hard to influence them in school. This is why the education sector has to make even more use of the existing support in order to reduce the underrepresentation of women in STEM jobs. In doing so, the goal should be a long-term creation of commitment and interest.

The New Zealand study *Progress at School* investigated boys' and girls' performances in English, maths and science in secondary schools and in coeducational and gender-segregated schools (Harker, 2000). It proved that gender-segregation does not have any advantages over coeducation. Further studies came to similar results and found that boys benefit from coeducation especially in linguistic areas (Van de Gaer et al., 2004). All in all, the results revealed how good an approach to the problem of uneven gender ratios and performances in specific subjects coeducation is. The studies also showed that group work has a beneficial effect on the performance and self-esteem of both genders as long as it takes place in a favourable atmosphere. 'Kolumbus-Kids' makes use of these findings as the

students work in small gender-mixed groups every session. The teachers encourage the students to form new groups every now and then to develop their social skills. The teachers also have an eye on the groups during group work, making sure every student is able to live up to his or her full potential. Experiences gathered in such group work phases and the positive feedback from other group members are a strong basis for a positive development of the children's self-esteem (Wegner, 2008).

While comparing several studies on gender issues in school, Faulstich-Wieland (2004) found it is important to depict sciences as a correlated system and to teach scientific facts with the aid of experiments, thus promoting a deeper understanding. This approach is the more successful the more varied such experiments are and the more sophisticated the didactic preparation of the topics is (Faulstich-Wieland, 2004). Therefore, 'Kolumbus-Kids' tries to use a broad variety of teaching approaches and to incorporate as many different experiments as possible over the course of the school year.

The Study: Emotions as factors to be observed

The project is coeducational and open for students with a special interest in and a heightened aptitude for sciences. This makes for different conditions compared to regular classes. In the following sections, different emotional characteristics which affect the students' interest and motivation will be described. In order to further improve the project and the tutoring of gifted children, the study aims at investigating how girls are different from boys when it comes to experiencing frustration, boredom and insecurity during science lessons. These emotions were chosen as they highly influence a person's activation, interest and motivation and are the point of intersection for cognitive processes (Hascher, 2005).

It was shown many times that positive emotions facilitate retrieving positively tainted memories, whereas negative emotions do the same with negative memories (Edlinger & Hascher, 2008). Theories about an associative network are regarded as a possible explanation for such findings. They postulate memories and terms are connected like knots, with similar ones being closer together than rather different ones. In the midst of these terms, there are emotional knots, and activating one of them also leads to the activation of surrounding knots. This would explain why certain emotions facilitate recalling certain memories. Such theories got further backing as research proved emotions have a definite effect on cognitive processes like taking in, selecting, processing and retrieving information, up to the point of completely changing and blocking ways of thinking (Edlinger & Hascher, 2008). This means knowledge taught at school is an emotion carrier. That in turn implies the learning outcome of students can be influenced by presenting information in appealing ways, using materials and methods which pay attention to the students' emotions (Edlinger & Hascher, 2008). Because of this, there is a good case to assume the creation of positive emotions in combination with taking individual interests and needs into consideration improves the learning outcome.

Frustration sets in if expectations are not met. There are countless possibilities this might happen in school classes, for example if a student does not get the praise he or she was hoping for after work is done or if the tasks given by the teacher are too difficult (Bach, 1996). It can also occur if the teacher misses listening to the students' answers. The resulting frustration negatively affects the level and quality of the effort put into learning. Generally speaking, the absence of positive emotions like happiness, relief and satisfaction results in disappointment. Stäcker (1977) terms such negatively perceived stimulations as aversive, also including punishment and stress. All in all, frustration can set in any time positive stimulations do not occur. Regarding girls in STEM subjects, this can happen when they are

not praised for their achievements or not paid attention to because of stereotypical thoughts regarding gender. The same applies for treating girls differently from boys in other situations.

When *boredom* sets in, time seems to go by slower, leading to a refusal to participate. It comes when the individual optimum of excitement, which is determined by features of the respective situation and the person's character, is not met anymore. In case there is not enough input by the teacher, especially gifted students can turn into underachievers, meaning they show bad performances in spite of their abilities. The resulting boredom has to be met with interesting facts and tasks in order to raise the child's attention again (Wegner, 2008). Students often find regular school classes boring despite the presentation of new knowledge. One main reason is that such classes do not meet the level of excitement students are used to from the new media that influence big parts of their lives. A possible solution to this problem is the use of projectors, smart boards and interactive learning software. Science topics offer countless possibilities for the exciting presentation of information, for example by using new media and linking the teaching contents to everyday phenomena. Ideally, every teaching unit should be didactically designed in a way that pays respect to the students' interests and aims at maintaining a high level of motivation to counter boredom (Wegner, 2008).

Insecurity. Piaget (1975) considers learning an active process with unique internal momentum. He states that insecurity can occur in students while dealing with previously unknown information which they are not able to integrate into their cognitive structures. The emergence of this emotion is the more likely to happen the more often the student encountered situations like this. Especially STEM subjects demand high levels of abstract thinking from students because of the models and formulae the respective information is condensed in. Such things have to be taught with care and integrated into already existing knowledge, otherwise the students' understanding will be hugely hampered. These situations are threatening to the girls' learning outcomes since girls are more prone to damage to their self-esteem than boys are. According to such findings, girls' performances are often worse in STEM subjects not because of lacking competence but because of a lowered belief in their own abilities (Bischof-Köhler, 2006). It is hence extremely important to praise students' and especially girls' achievements during classes.

Research Methodology

Objectives and Hypotheses

The project aims at tutoring girls and boys at the same time and with the same intensity to keep their interest in sciences alive and growing. The ultimate aim is to prevent frustration, boredom and insecurity from coming up, thus maintaining a high level of motivation. To see whether the negative development of girls' interest and motivation often found in STEM subjects can be prohibited within the project, this study aims at comparing the girls and boys over the course of six months. The hypotheses are as following.

H1: The girls' frustration within the project 'Kolumbus-Kids' does not get significantly higher compared to the boys over the course of one year.

H2: The girls' boredom within the project 'Kolumbus-Kids' does not get significantly higher compared to the boys over the course of one year.

H3: The girls' insecurity within the project 'Kolumbus-Kids' does not get significantly higher compared to the boys over the course of one year.

Sample and questionnaire

In order to understand the emotions' influence on the students' willingness to perform, they had to be investigated in a differentiated way. For this purpose a questionnaire developed (Table 1) and successfully tested regarding its reliability, objectivity and validity by Wegner (2008) was used. 20 girls and 29 boys aged nine to eleven had to answer the items shown in tables 1-3 with a four-step scale. This four-step scale enabled them to choose between the four answers 'completely agree', 'partly agree', 'partly disagree' and 'completely disagree'. The test was conducted twice between autumn 2010 to spring 2011. Before entering the project, the students had to do a cognitive abilities test which was built on the basis of the Lorge-Thorndike Intelligence Test (Lorge & Thorndike, 1954) as well as the Cognitive Abilities Test developed by Thorndike, Hagen and Lorge (1954-1974). It suits children aged nine to 18 and covers several areas of abilities from linguistic via arithmetic to exemplary thinking. Its result is a good picture of the overall cognitive abilities of a child (Heller & Perleth, 2000).

To take part in the project, the children have to have an intelligence quotient of at least 120, so all of the participants in this study can be regarded as gifted. The collected data was assessed with a complete analysis, meaning only answers from students who participated in all tests were used. The results were tested for significance using univariate two-way analysis of variance. This allows for an investigation of results from a multi-group sample (females and males) tested for several features (frustration, boredom, insecurity) more than once, while separating and comparing the different groups' features with one another (Bortz & Schuster, 2010). This comparison reveals differences in the developments of the various emotional features between the girls and boys, thus showing whether these differences are significant or not. For significant effects adjusted effect sizes were calculated (partial eta-square, η^2) to get the share of variance which was clarified by independent variables compared to the overall variance of the sample group (Holling & Gediga, 1999). According to Cohen (1988), figures of .01 should be considered small, .06 medium and 0.14 big. In the following, the data found in this study will be presented. Lower average values mean the students agreed with the corresponding items on the respective emotion less. For better visibility, the diagrams only show the section from 1 to 2.2.

Table 1. The questionnaire

Items on frustration
The classes have been very frustrating for me lately
I was actively involved in the topics during the last classes
I did not know what to make of the last lessons
I did not understand what was going on in the last lessons
In the last couple of lessons, I understood so little it was annoying
Items on boredom
I noticed I was not paying attention much in the last lessons
It felt like the last lessons were never going to end
I focused on other things many times during the last lessons
I felt like time went by really fast in the last lessons
Items on insecurity
The last couple of classes made me feel very confused
I did not get much of the information presented in the last lessons
I do not know why we dealt with these topics in the last sessions
I had trouble organising the information presented by the teacher in my mind during the last lessons

Results

Frustration

The hypothesis regarding frustration stated that the girls' frustration within the project would not get significantly higher compared to the boys over the course of one year, thus implying girls are at least tutored as well as boys are. An analysis of variance showed there is a highly significant difference between the two sample groups [$F = 7.734$, $p < .008$, $\eta^2 = .141$], with the girls constantly showing lower frustration than the boys. However, the latter's frustration becomes slightly less distinct over the course of the study, falling from 1.48 to 1.46 between the two tests (see Figure 1). With all means below 1.5, both groups show very little frustration.

Boredom

Hypothesis H2 assumed the girls' boredom within the project does not get significantly higher compared to the boys over the course of one year. Again, there is a significant difference between both groups [$F = 6.366$, $p < .015$, $\eta^2 = .119$]. Although both groups' boredom gets lower over the course of the study, the girls are constantly less bored compared to the boys (see Figure 2).

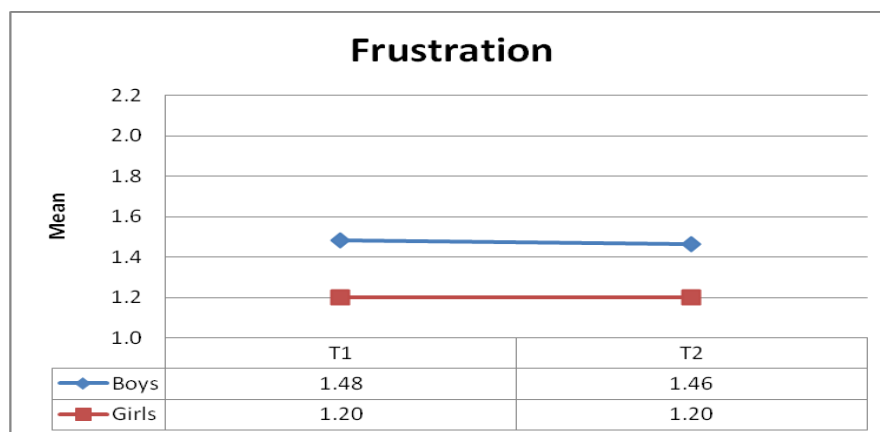


Figure 1. Development of frustration in girls and boys over the course of the study

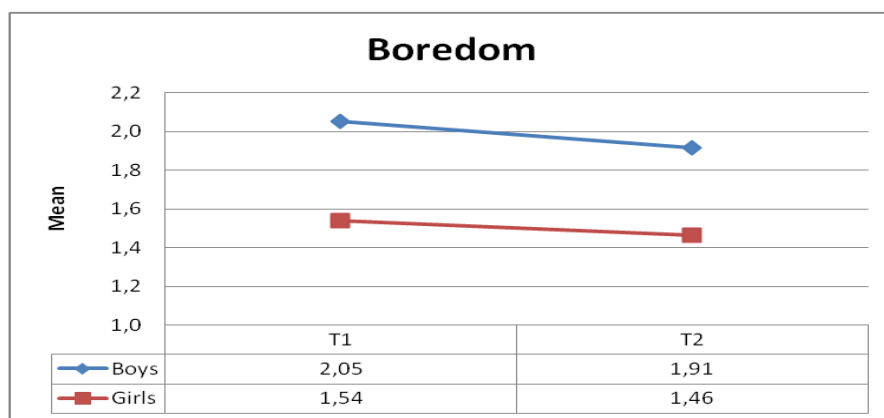


Figure 2. Development of boredom in girls and boys over the course of the study



Figure 3. Development of insecurity in girls and boys over the course of the study

Insecurity

The last hypothesis said the girls' insecurity within the project does not get significantly higher compared to the boys over the course of one year. The analysis of variance proved there are no significant differences between the sample groups but light tendencies [$F = 3.176$, $p < .081$, $\eta^2 = .063$]. However, a t-test comparing the means of both groups at the second test came to a significant result [$T = 2.027$, $df = 46.297$, $p < .048$]. Both groups' insecurity gets lower from the first to the second test, with the girls showing smaller means than the boys (see Figure 3). The data revealed the girls' means are always below the boys'. Both groups show low manifestations regarding each of the tested emotions. Also, frustration, boredom and insecurity get even lower in almost every case from the first to the second test.

Discussion

The results showed girls are less frustrated (hypothesis 1) and bored (hypothesis 2) than the boys during the project. They also show less signs of insecurity (hypothesis 3). This might be the case since teachers in the project trust all children with experimental apparatuses they have not encountered before or let them deal with animals of every kind. Of course, the teacher is present at all times, but rather acts as a facilitator which increases the girls' feeling of security once they feel they also succeed in doing things on their own. This also happens when they experience that they are able to conduct a serious experiment on their own without much help of the teacher. In situations like these they consider themselves competent and thus their performance in STEM subjects will increase (Bischof-Köhler, 2006). Even though an experiment might not work out as planned every time, the children are nevertheless given the freedom to conduct it themselves without being controlled permanently. Another factor decreasing the girls' insecurity (hypothesis 3) is the limited group size. The project's classes consist of a maximum of 15 pupils which suggests the assumption that pupils feel less embarrassed when they get something wrong. Due to the preparatory seminar the trainee teachers are equipped with several strategies of coping with insecure students.

However, the data collected from both genders suggests both are content within the project for all means are quite low. The results suggest that the coeducational approach of 'Kolumbus-Kids' is the right way to go about building self-esteem and increasing the pupils' general performance. Apparently, the findings go along with Harker's study (2000). The

data also reveals boredom, insecurity and frustration decrease over the course of the project, thus proving the program's concept works out fine.

With reference to H1, one possible reason for the girls' low frustration might be the active reduction of stereotypical ideas and thoughts amongst the project's participants by the teacher. In classes where it is mostly the girls who participate voluntarily, they are not called up anymore at some point as the teachers recognise the imbalance of pupils' responses. However, this is perceived as punishment by the girls (Stäcker, 1977) and might eventually turn into frustration. During 'Kolumbus-Kids' classes this is not the case since the group size is relatively small and there is the general tendency to involve as many pupils as possible at the same time, for example in group work. By that, permanent contribution to the lesson is guaranteed and frustration is less likely to occur. The innovative approach to teaching is possible since the teacher trainees holding the lessons are not only taught about issues regarding giftedness but also about such concerning gender and teaching practice in the theory seminar beforehand. This guarantees a fair treatment of boys and girls alike as it enables the teachers to have a 'gender-free' mind when assessing both groups' performances. The results found in studies like the one at hand also influence the future topics and the design of the theoretical seminar accompanying the project, thus making for an ever-improving preparation of the teacher trainees. This in turn hopefully results in further falling values regarding boredom, frustration and insecurity in future 'Kolumbus-Kids' classes.

The project's structure also enables the teachers to directly notice and react to problems as the classes only consist of around 15 students. This reduces boredom, thus calling on hypothesis 2, on a large scale since no student has to sit and wait for long in case he or she encounters difficulties. As the lessons span a whole school year, there is also enough time to fully integrate the girls into the groups and to get to know their strengths and weaknesses, thus making for the best support possible. Another reason for the low amount of boredom is the fact that only such girls interested in sciences take part in the project. This in fact makes it easier for the projects' teachers to design pleasing and interesting lessons. Due to the excellent facilities and equipment of the university, using new media and many different animals arouses the pupils' interest all the more which results in positive emotions. As mentioned before, this is a prerequisite for knowledge increase (Edlinger & Hascher, 2008). Boredom does also not occur since the topics dealt with are new to the pupils and have not already been covered in the regular school setting, thus yielding heightened attention (Wegner, 2008). Also, the general setup of a 'Kolumbus-Kids' class stresses pupils' independent activity, for example when they are asked to conduct an experiment on their own. Instead of presenting all findings in a tiring way, pupils have to engage in the research process which again prevents boredom.

The hands-on STEM classes furthermore support girls in a special way. The practical exercises facilitate understanding the presented information as they make the knowledge more tangible. On the other hand, the group work the experiments are conducted in train the girls' social skills, thus enhancing their self-esteem and courage while reducing uncertainties. The reasons for the significant differences between the boys and the girls may be found in their regular classes. As Dietzold (2003) suggests, girls make more negative experiences there because boys draw more attention than girls, thus also getting more praise in case of good performance. This supposedly negative preset makes the benefits of the project's design for the respective parameters within the girls even more apparent.

Some suggestions for practice that you can conclude from this successful project would be first and foremost: praise. Praise every pupil for his or her contribution so that regular participation is not hindered. By that, frustration and insecurity will most certainly range at

a constantly low level. In case the group has not known each other for a long time, it might be a good idea to have girls and boys working in different groups at first until their self-esteem is raised. After that, especially the girls will be brave enough to 'compete' with the boys' performance. In order to encourage a positive self-perception and to reduce boredom, design action-oriented lessons where girls experience their ability, are challenged at just the right level and have fun as well.

Conclusion

As found in this article, the underrepresentation of women in STEM-related university classes is a problem that has to be solved not only because of the skilled labour shortage. The study shows that specifically designed tutoring projects like 'Kolumbus-Kids' contribute highly to this solution. They are able to ignite and keep the interest in STEM-related subjects alive and they also lower frustration, boredom and insecurity in the same regard. One of the most important prerequisites for success is to know the girls' interests and what the possible problems are in order to better support them. Of course, projects like this approach only a limited number of children. Still, it is a precious way of facing skilled female worker shortage and might be adapted in parts to regular school settings as well. Since schools' facilities cannot provide the same setting as bigger institutions such as universities the results regarding frustration and boredom might not equal the ones of this study. Yet by just following some of the suggestions for practice, girls will definitely benefit and develop a heightened interest in the science, which then would have to be promoted with the help of tutoring projects and alike.

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