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Comparing (Out of) School Learning in a Student Laboratory with Regular Biology Lessons

Claas WEGNER [1], Mario SCHMIEDEBACH [2]*

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Abstract

Out-of-school laboratories offer the chance to teach science action-oriented and problem-based in an original context. The effectiveness of out-of-school laboratories has primarily been investigated by changes in the student's attitude before and after the visit, however, the direct comparison between the regular science class and the out-of-school teaching has so far mostly been neglected. The present study closes the current gap by allowing the students to directly compare both learning situations (workshop in the laboratory and the regular biology lessons) in a questionnaire study (N = 163). Results show that the out-of-school learning situation implements facets of moderate constructivism (active and social) significantly better and a higher value of interest is achieved in comparison to the regular biology lessons in school. Moreover, frustration is significantly lower at the out-of-school laboratory. Rank order correlation implies coherence between the previous knowledge concerning the topic of the workshop and the other factors. Prospectively, a preparatory script for each workshop will be developed to allow better preparation in school and guide the teachers.

Keywords: Biology education; evaluation; out-of-school learning; student laboratories

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[1] PhD, Professor and lecturer, Bielefeld University, Bielefeld, Germany, Email: claas.wegner@uni-bielefeld.de
[2] PhD, Bielefeld University, Bielefeld, Germany, Email: mario.schmiedebach@uni-bielefeld.de
* Corresponding author

1. Introduction

In recent years, a special kind of "non-formal student laboratories" (Affeldt et al., 2015, p. 239) has emerged in Germany: the so-called *Schülerlabor* (student laboratory). There has been an increase in the number of student laboratories since the turn of the millennium[2] – partly because of poor results in international comparative studies like PISA or TIMIS, partly because of a general observable decline in interest in the natural sciences (in Germany). The new competence-oriented educational standards that have been developed after the devastating results of these international studies emphasize the importance of practical, hands-on work. Through science education, students should also learn and explore the nature of science, hence, how science works (Di Fuccia, Witteck, Markic, & Eilks, 2012, p. 60). Student laboratories as extracurricular places to learn are a potentially crucial factor in promoting student interest and practical experience since hands-on work, and particularly inquiry-based learning, is still quite limited in German classrooms (Di Fuccia et al., 2012, p. 60), oftentimes due to a lack of equipment or high costs (Garner, Hayes, & Eilks, 2014, p. 19). Student laboratories can be seen as an environment "where students engage in planning learning experiences and interact with materials to observe and understand phenomena" (Hegarty-Hazel, 1990, p. 4).

Today, more than 300 student laboratories[3] with different thematic foci exist all over Germany. Many of them are in some way connected to universities or larger research institutes (Affeldt et al., 2015, p. 239). Originally, laboratories were predominantly intended to foster "older and higher achieving students" (Affeldt et al. 2015, p. 239), there have been developments to make them accessible to a larger body of students, to foster interest in the sciences and to potentially motivate students to pursue a career in the field (Garner et al., 2014, p. 19). A typical visit to a student laboratory is planned as a compulsory half- or full-day excursion set up by the teacher (Affeldt et al., 2015, p. 239).

While being part of a student laboratory, students should actively and independently and in cooperation with their peers obtain new insights through experimenting and reflecting (Engeln & Euler, 2004, p. 45). The overall goal of student laboratories can thus be described as "the promotion of interest and open-mindedness of children and adolescents towards natural sciences and technology as well as conveying an up-to-date image of the subjects and their meaning for our society" (Euler & Weßnigk, 2011, p. 32). Euler and Weßnigk (2011, p. 33) further name the following goals:

- Encountering modern natural and engineering sciences through experienced-based approaches to processes of research and development;
- Creating a learning environment that fosters active engagement with real-life problems in research and technology;
- Offering the chance to gain experiences through experimenting and practical activities
- Offering ways to learn and grow through team and project work;
- Enabling students to work on challenging tasks and problems and making them solvable through providing adequate scaffolding;
- Fostering technical as well as interdisciplinary competences;
- Giving an insight into potential careers in science and technology;
- Giving students the chance to establish contact with scientists and potential role models, particularly for girls and young women.

[2] In their report, Singer, Hilton, and Schweingruber (2006) stress that there is a lack of a unified definition for the term student laboratory. Many different forms of such laboratories exist, particularly considering an international context. In this paper, student laboratories are considered extra-curricular learning environments which high school science classes can visit as a field trip usually for one day in a workshop-like manner.

[3] See also Psillos and Niedderer (2002) for more details on potential classifications for student labs.

Despite their central role in promoting interest in the sciences through hands-on experiences out of the oftentimes restricted school context, the question remains about how effective laboratory work is in facilitating student learning and understanding (Psillos & Niedderer, 2002, p. 1). The next section will thus take a closer look at empirical research investigating laboratory work and its effectiveness.

2. Effects of student laboratories

Considering the intention of student laboratories to foster interest in science through practical experience and inquiry-based learning, there has been some debate surrounding the effectiveness of student laboratories, e.g. due to short contact time. Having a look at studies investigating such effectiveness, there is rather limited empirical work investigating the effects of out-of-school student laboratories in Germany (Di Fuccia et al., 2012, p. 68). Additionally, empirical work focusing on student laboratories has been quite heterogeneous (Guderian & Priemer, 2008, p. 28).[4] Most of the studies conducted in the German context are a) based on dissertations, b) involve some form of pre-post-follow-up design, and c) are connected to various subjects, e.g. Glowinski (2007) and Scharfenberg (2005) for Biology, Engeln (2004), Guderian (2007), and Pawek (2009) for Physics, or Brandt (2005) and Zehren (2009) for Chemistry. Studies support a positive effect on interest in natural sciences (Brandt, 2005; Engeln, 2004; Pawek, 2009) and different dimensions of interest. The positive effect on interest is not connected to gender (Euler, 2001) and could potentially cause a positive change in girls' self-efficacy over a longer period (Pawek, 2009, p. 11).

In this review and despite the studies' heterogeneity in terms of subjects, participants, or operationalization, it becomes apparent that visiting such laboratories may impact affective components, such as interest. However, such effects are rather short-term and not sustainable (Guderian & Priemer, 2008, p. 31). They do not last long, if laboratory visits are implemented sporadically and detached from actual school life and the in-school teaching. If the topics covered in the laboratory are not in line with what students do in their science classes at school, they often cannot establish a link between knowledge gained in this non-formal learning environment and learning in school (Garner et al., 2014, p.19). The frequency of visits also impacted the overall effects of student laboratories: if students visit the laboratory only once in six months, the effects connected to motivation are only minor (Garner et al., 2014, p.19).

The student laboratory in this study was established at Bielefeld University in 2009 and belongs to the Department of Biology, more specifically Didactics of Biology (Wegner & Strehlke, 2015). It is conceptualized for junior and senior students (ages 13 to 18). The workshops are supervised by staff members of the department or biology student teachers as a part of their studies at the university. All topics offered in the workshops are based on the respective curricula and cover a wide range of topics, such as

- bionics: taking nature as a model (e.g. geckos and their ability to walk on walls);
- photosynthesis: processes involved in photosynthesis and their transfer to other technological processes;
- human and animal behavior: classic and operant conditioning, working with living animals;
- maritime biology: the sea as a living environment (e.g. ecology, characteristics of animals living in the sea);
- reanimation: the heart and circulatory system (e.g. from a pathological point of view, practicing cardiac massage, working on mechanisms involved).

[4] See also Guderian and Priemer (2008) and Röllke (2019) for a comprehensive overview of studies conducted in Germany.

All workshops focus on independent experimenting and problem-solving in small groups, always sticking to scientific ways of generating and testing knowledge (figures 1 and 2). Conforming with our definition stated at the beginning of this article, workshops offered at the student laboratory were conceptualized as an extra-curricular activity that school classes visited as a part of a field trip. Except for one workshop being planned as a holiday camp, all other workshops lasted one day (between 5 to 8 hours).

Figure 1. A student investigates the lotus effect in an experiment (left); a group conducts the "blue-bottle"-experiment as part of the photosynthesis workshop.

Figure 2. A student feeds a chameleon to observe the hunting method (left); students investigate the structure of a shark skin under the binoculars and with a model.

3. Methods

3.1 Research aim

Apart from the aforementioned focus on factors such as interest, motivation, or knowledge gain in a pre-post-test design, there is a lack of studies investigating student laboratories in comparison with regular classes at school. The present study aims to close this research gap by focusing on this direct comparison between workshops as a part of a student laboratory and regular Biology classes, posing the following research question:

- How do students evaluate the extracurricular learning environment of the workshop compared to regular biology classes at their school?

The second research question investigates students' prior knowledge regarding the particular workshop's topic and their evaluation of the workshop:

- How do students' self-assessed prior knowledge regarding the workshop topic and their evaluation of the workshop correlate?

The study aims to investigate to what extent facets of moderate constructivism are implemented as well as how both learning environments (school vs. student laboratory) promote interest and prevent frustration. Additionally, we are taking a closer look at the competence areas of *knowledge production* and *communication* by letting students assess both learning environments about fostering these two competences.

It was assumed that the students' interest in the workshop was significantly higher when compared to regular Biology classes, while their frustration was significantly lower. It was further assumed that students perceive their learning as more active and social when compared to regular Biology classes since they work independently in small groups.

Tasks and experiments in the workshop are based on the scientific method (Schmiedebach & Wegner 2019, p. 24), therefore, it was assumed that students would experience a significant increase in knowledge production when compared to regular Biology classes. A significant increase in communicative competences is also expected due to small group sizes in the student laboratory.

3.2 Participants

A total of N=163 students participated in the study (out of which 46.6 % were female, the average age: 15.78 years, SD=1.17)). Students in the sample were attending the school types *Gymnasium* (n=47), *Gesamtschule* (n=102) as well as *Sekundarschule* (n=14).

Participants visited different workshops in the student laboratory: maritime biology n=22, photosynthesis n=53, reanimation n=10, human and animal behavior n=56, and bionics n=22.

3.3 Instrument

The questionnaire used in this study consisted of nine items dealing with general academic and subject-specific biological self-concepts (see Table 1) as well as 28 items comparing the workshop as an extracurricular learning environment with regular Biology lessons the students experienced so far (see Table 2). Items had to be rated on a six-point Likert scale ranging from *strongly disagree* to *strongly agree.* Additionally, socio-demographic data such as grade, type of school, and prior knowledge were included.

Table 1. Overview of scales self-concept (general) and self-concept (biological) with Cronbach's α values.

Scale	Number of items	Cronbach's α	N
Self-concept (general) (Wegner, 2009)	5	.787	156
Self-concept (biological) (Wegner, 2009)	4	.774	152

Table 2. Overview of scales facet of moderate constructivism *(active participation, social interaction,* and *constructive behavior*), frustration, interest, and competence areas communication and knowledge production used for the questionnaire comparing workshops of the student laboratory (WS) and regular Biology lessons (BL) with number of items and respective Conbach's α values.

Scale	Number of items	Cronbach's α (WS)	N	Cronbach's α (BL)	N
Facet of moderate constructivism – *active participation* (Basten et al., 2015)	3	.829	159	.871	153
Facet of moderate constructivism – *social interaction* (Basten et al., 2015)	3	.740	160	.771	159
Facet of moderate constructivism – *constructive behavior* (Basten et al., 2015)	4	.876	159	.888	153
Frustration (Wegner, 2009)	5	.800	156	.859	153
Interest (Wegner, 2009)	3	.887	158	.889	157
perceived knowledge acquisition [ISQ (2009/2010)]	5	.801	153	.877	152
perceived scientific communication skills [ISQ (2009/2010)]	4	.811	154	.839	152

3.4 Procedure

The questionnaires were handed out to the students after the respective workshops. Results were then analyzed using SPSS 24.0. For comparing results for the workshop as the extra-curricular student laboratory setting and regular biology lessons, dependent t-tests were performed.

Kendall's tau coefficient was used to investigate a potential correlation between students' self-assessed prior knowledge regarding the workshops' topics and the constructs of interest, frustration, as well as knowledge gain.

4. Results

4.1 Comparison: workshop with regular Biology classes

To investigate the first research question (see above), results for the facets of moderate constructivism (active, social, constructive), as well as frustration, interest, and competence areas communication/knowledge production were compared for the workshop setting and regular Biology classes using a dependent t-test (see also Table 3).

Table 3. Sample size (N), mean (M), standard deviation (SD), t value (T), degrees of freedom (df), p-value (Sig), as well as Cohen's d (Effect d) for scales facets of moderate constructivism (active, social, constructive), as well as frustration, interest, and competence areas knowledge production and communication with *p < .05, **p < .01 und ***p < .001.

	N	M	SD	T	df	Sig. (two-	Effect d

							sided)	
Facet of moderate constructivism – *active participation*	WS	160	4.65	.95	3.32	159	.001**	-0.30
	BL	160	4.34	1.09				
Facet of moderate constructivism – *social interaction*	WS	160	5.14	.83	8.53	159	<.001***	-0.76
	BL	160	4.43	1.02				
Facet of moderate constructivism – *constructive behavior*	WS	160	4.59	1.05	1.66	159	.098	n.s.
	BL	160	4.46	1.01				
frustration	WS	161	2.06	.88	-6.32	160	<.001***	0.47
	BL	161	2.53	1.10				
interest	WS	159	3.97	1.13	2.12	158	.036*	-0.20
	BL	159	3.74	1.21				
perceived knowledge acquisition	WS	157	4.10	.99	1.60	156	.112	n.s.
	BL	157	3.95	1.12				
perceived scientific communication skills	WS	157	3.74	.96	-2.84	156	.005**	0.25
	BL	157	4.00	1.10				

Significant differences between workshops and regular Biology classes could be observed for the facets of moderate constructivism active and social, as well as for frustration, interest, and communication. The facets of moderate constructivism (active and social), along with interest are significantly higher in the workshop compared to regular Biology classes (t_{pcc_active} (159) = 3.32, p = .001 bzw. T_{pcc_social} (159) = 8.53, p < .001 bzw. $T_{interest}$ (159) = 2.12, p = .036). Results for frustration (t(160) = -6.32, p < .001) and communication (t(156) = -2.84, p = .005) were significantly lower in the workshop setting

4.2 Influencing factor prior knowledge

For investigating the second research question, potential connections between students' prior knowledge and the workshop rating in terms of interest, frustration, facets of moderate constructivism, and knowledge gain were examined using Kendall's tau coefficient.

Results showed a positive correlation between self-assessed prior knowledge regarding the workshop's topic and interest in the workshop (τ(156) = .28, p < .001), the facet of moderate constructivism constructive (τ(159) = .27, p < .001), as well as knowledge gain (τ(155) = .24, p < .001). A negative correlation between self-assessed prior knowledge regarding the workshop topic and frustration (τ(159) = -.36, p < .001) (see also Table 4).

Table 4. The rank correlation between prior knowledge and interest, frustration, pcc constructive, and knowledge production in the workshops. **=correlation is significant for 0.01 (two-sided).

	Prior knowledge	**Interest (WS)**	**frustration (WS)**	**Knowledge production (WS)**	**pcc constructive (WS)**

Kendall' s tau - prior knowledge	Correlation coefficient	1.000	.28**	-.36**	.24**	.27**
	Sig. (two-sided)		<.001	<.001	<.001	<.001
	N	159	156	159	155	159

5. Discussion

Comparing the workshop(s) and regular Biology lessons showed that students perceived the two settings differently. Interest is significantly higher for the workshop setting which could be due to the workshop's strong focus on practical work and activity orientation. This activity orientation is mostly due to the numerous experiments students conduct in small groups during the workshop.

Research has shown that experimenting positively influences students' independent and creative thinking (Gropengießer, 2006, p. 265), facilitates the learning process through own actions (Adamina & Möller, 2013, p. 107), interest (Greinstetter, 2008, p. 65), motoric skills (Gropengießer, 2006, p. 265), social competence, as well as motivation (Wagener, 1992, pp. 117–122). Compared to student laboratories, experiments are rather rarely conducted in regular biology lessons because of the topics in the curriculum that need to be covered and organizational difficulties (e.g. in terms of equipment). The different methodological approaches in student laboratories could cause a significant difference in situational interest. In addition to that, the fact that another instructor is giving the workshop as well as the more informal atmosphere could potentially influence interest (see also Röllke, 2019, p. 34).

The positive effects of experiments can also be observed in the data: student frustration is significantly lower in the workshop setting since their learning process is facilitated through their active engagement. This active engagement is paramount to the workshop setting and often not applied in regular Biology lessons. This also causes the students to perceive themselves as more active than in a regular biology teaching setting.

There was no significant difference for the facet of moderate constructivism *constructive*, as regular Biology lessons are also based on the students' prior knowledge. Differences between the facet *social* for the workshop and the regular teaching setting were in accordance with Gropengießer (2006), as experimenting seems to have a positive effect on social competences. Even though it cannot be inferred from the data how regular Biology lessons are conducted, conducting experiments in small groups in the workshop setting seems to be different from regular lessons.

Students did not perceive a significantly higher increase in the competence areas of knowledge gain and communication when compared to regular Biology classes. Students evaluated the improvement of the competence area communication as significantly higher for Biology lessons. These results might be due to the workshop's conception. During the workshop, theoretical knowledge should be conveyed and deepened through practical experiments. In Biology lessons, there could potentially be a stronger focus on scientific/specialized texts, tables, and diagrams as these aspects are more relevant for assessment.

The second question investigated the effect of subjectively self-assessed students' prior knowledge on the workshop topic. An investigation of this correlation could contribute to a better understanding of which factor could be improved to maximize positive outcomes of visiting the student lab. Kendall`s tau coefficient was used to investigate correlations between self-assessed prior knowledge and the scales of interest, frustration, the competence area knowledge gain, as well as the facet of moderate constructivism *constructive*. Studies have shown that students with unfavorable learning preconditions such as a low domain-specific prior knowledge learn better in teacher-focused and highly structured environments. While for students with favorable learning preconditions, greater autonomy is more effective (Pawek, 2009, p. 69).

Since the workshops in this project are usually action-oriented and not teacher-centered, prior knowledge seems to be an important factor. While there was a positive correlation between prior knowledge regarding the workshop's topic and interest in the workshop, self-assessment of the competence area knowledge gain, and the facet *constructive* of (moderate) constructivism, results revealed a negative correlation between prior knowledge and frustration. These results are in line with other relevant research that has been conducted: Zehren (2009) states that an increase in interest is significantly connected to preparing the laboratory visit at school. This preparation could be inferred for our case when looking at the results for self-assessed prior knowledge regarding the workshop topic. This is in line with the result of Sunal, Sunal, Sundberg, and Wright (2008) who stress a better integration of laboratory visits into regular lessons at school to obtain an overall better learning effect. This is also connected to the negative correlation between prior knowledge and frustration since experiments are more comprehensible and can be seen within a wider context.

Preparing the experiments and their theoretical backgrounds in school is also more in line with a constructivist approach to learning since students then have the prior knowledge to use as a basis and to expand on while conducting practical experiments (Pawek, 2009, p. 176). Reinmann and Mandl (2006) stress that prior knowledge and skills need to be present to some extent for the students to be able to build upon them. Huwer (2015) views prior knowledge as essential for a successful learning process. Dealing with the knowledge required for the student lab does not have to be a time-consuming activity, as results of Runge, Stiefs, and Schecker (2013) show: even after a 90-minute preparation lesson, students showed an increase in prior knowledge and motivational variables.

6. Conclusion and implications

Taking a look at our results about previously generated hypotheses, the extracurricular learning environment was generally evaluated positively. Regular Biology lessons served as a comparison group. Students assessed the workshop as particularly activating and social with regard to process characteristics of (moderate) constructivism. Additionally, student interest was significantly higher, and student frustration was significantly lower when compared to regular Biology classes. Results for communication were significantly lower when compared to regular Biology lessons. This could be due to a higher competence and curriculum orientation in regular Biology classes. Additionally, rank correlations showed that prior knowledge plays an important role when it comes to evaluating the extracurricular offer: the higher the subjectively perceived prior knowledge, the more students are interested in the workshop and the higher are scores for knowledge gain. At the same time, results for frustration declined with an increase in prior knowledge.

This leads us to stress that visiting extracurricular offers such as student labs needs to be prepared more in school. Zehren (2009) stresses that deficits in prior knowledge can be compensated through the quality of instruction, however, student laboratories can also influence the factor prior knowledge relatively easily. Scripts could be given to the respective teachers to create a basis for mandatory knowledge such as specific terms, concepts, or methods used in experiments. This way, teachers would be able to prepare students for their visit without any additional work on their part while at the same time, students would profit even more from visiting the extracurricular offer.

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