Studies in Educational Evaluation 39 (2013) 161–168

Contents lists available at SciVerse ScienceDirect

Studies in Educational Evaluation

journal homepage: www.elsevier.com/stueduc

Out-of-school learning in the botanical garden: Guided or self-determined learning at workstations?

Franziska Wiegand [a,*], Alexander Kubisch [b], Thomas Heyne [a]

[a] Fachgruppe Didaktik Biologie, Biozentrum, University of Würzburg, Matthias Lexer Weg 25, 97074 Würzburg, Germany
[b] Field Station Fabrikschleichach, University of Würzburg, Glashüttenstr. 5, 96181 Rauhenebrach, Germany

ARTICLE INFO

Article history:
Received 17 December 2012
Received in revised form 26 May 2013
Accepted 5 June 2013

Keywords:
Student-centered
Workstations
Teacher-centered
Self-determination theory
Botanical garden
Intrinsic motivation inventory

ABSTRACT

Guided tours are the method of choice for school classes visiting botanical gardens. However, it remains unclear, which influence such teacher-centered approaches have on learning outcome in such informal learning environments. We compare a teacher- to a student-centered *learning at workstations* program under the topic *plants and water*. 16 school classes at eighth grade visited the botanical garden of the University of Würzburg, attending either one of both treatments. We used multiple-choice questionnaires measuring knowledge scores and found no significant differences in learning outcome – tested in a pre-post-retention design. We also monitored the students' intrinsic motivation, which resulted in similar and high scores. Possible causes for our results and consequences for education at botanical gardens are discussed.

Introduction

Out-of-school learning settings reveal positive cognitive outcomes

"Field trips to museums, zoos and science centers or the natural environment could deepen students' understanding of subjects usually taught in the classroom" (Sturm & Bogner, 2010, p. 14). The named institutions as well as botanical gardens meet all demands of out-of-school learning settings. For example, the demonstration of living or "dried" animals/organisms could transport more information and could change students' beliefs and affective reactions, like the fear of snakes (Bitgood, 1989). Compared to classrooms, education of global environmental sciences at out-of-school learning settings is possible in a more visual, visceral and trans-disciplinary way (Storksdieck, 2006). Teachers often make use of field trips to such settings to complement and supplement their instructions (Ackermann, 1998), as well as to form class cohesion and to increase the students' motivation (Storksdieck, 2006). Hence, in recent years many studies, especially in science education, focused on this topic. Researchers have mainly been interested in the comparison between classroom-based teaching and different out-of-school learning settings. Results of these studies showed a cognitive benefit of the out-of-school settings at museums (Sturm & Bogner, 2010), laboratories (Scharfenberg, Bogner, & Klautke, 2007) and science centers (Dairianathan & Subramaniam, 2011). Yet, for a salt mine, Meissner and Bogner (2011) measured cognitive levels, which were comparable to those achieved in classrooms. Still, in all of these interventions students showed a significant increase in knowledge about the particular topic at the respective out-of-school learning setting.

Botanical gardens as informal learning environments

Nowadays botanical gardens in Germany are not only museums for plants under the motto "don't touch". For instance, in some German cities, like Frankfurt am Main, Heidelberg, Ulm and Mainz, so-called "green schools" or "green classrooms" add an educational and sustainable component for all age groups of garden visitors, but especially for students in schools and universities. In the surroundings of a few, especially large, cities, several landscape forms, like for example meadows and forests, can only be found in botanical gardens. Consequently, botanical gardens are today not only responsible for the rearing, cultivation and research of plants, but also for the comprehensive communication of knowledge in a didactically appropriate manner. Trips to botanical gardens allow a teacher to be comparably flexible regarding the topic and offer opportunities to meet and involve experts. Additionally, botanical gardens are not necessarily learning environments focused on botany or even biology. Besides topics like adaptation or plant–animal

* Corresponding author. Tel.: +49 931 31 83598.
E-mail address: franziska.wiegand@biozentrum.uni-wuerzburg.de (F. Wiegand).

0191-491X/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.stueduc.2013.06.001

interactions, students can there potentially also learn about for example geography or natural or human history. Hence, an important current task of botanical gardens, namely environmental education and education for sustainable development (Willison, 2006), can effectively be addressed.

Botanical gardens are informal learning environments (Sellmann & Bogner, 2012), as they fulfill the four preconditions summarized by Storksdieck (2006): 1. Media are present to visualize the botanical and/or global context. 2. Botanical gardens have to be visited by the students. 3. Students get the chance for primary encounters with plants and animals and gain knowledge about species and 4. They can learn about ecological and environmental issues (Killermann, Hiering, & Starosta, 2011). Additionally, out of school lessons tend to be more open and socially interactive (Hofstein, Nahum, & Shore, 2001). The atmosphere is often more relaxed (O'Brien & Murray, 2007), bearing no school time pressure in concert with a non-evaluative nature. All of these advantages can potentially foster the learning of students. Sellmann and Bogner (2012) found significantly higher knowledge scores for 10th graders following an instruction in a botanical garden for the topic of climate change. They also measured the students' attitudes toward utilization and preservation of nature, according to the Two Major Environmental Value model of Bogner and Wiseman (2006). Also, Drissner, Haase, and Hille (2010) investigated effects of a short-term education program regarding small animals in the ''green classroom''. Both analyses revealed positive effects of the interventions in botanical gardens on the utilization, but not on preservation values. Furthermore, the intrinsic motivation of the involved students was higher in comparison to control groups (Drissner et al., 2010). Thus, education programs in botanical gardens could influence cognitive, affective and motivational attitudes positively.

Intrinsic motivation inventory (IMI)

In this study we investigate, adjacent to the learning outcome, whether students are intrinsically motivated for the topic *plants and water* in the setting of a botanical garden. In this context we make use of the intrinsic motivation inventory (IMI), established by Deci and Ryan in 1985. The IMI is based on self-determination theory, which suggests that people are intrinsically motivated when doing something inherently interesting or enjoyable (Ryan & Deci, 2000). In contrast, extrinsic motivation results in low-quality learning, because the act itself leads to an extrinsic, separable outcome, like a grade for instance. However, intrinsic motivation results in high-quality learning and creativity (Ryan & Deci, 2000), which is desirable in education research.

Student-centered vs. teacher-centered approaches

Few studies in the last decade dealt with the effects of student-centered against teacher-centered methods at out-of-school learning settings, like laboratories (Abrahams & Millar, 2008; Scharfenberg et al., 2007; reviewed by Hofstein & Lunetta, 1982, 2004), natural history museums (Wilde, Urhahne, & Klautke, 2003) or zoos (Randler, Kummerer, & Wilhelm, 2011). Scharfenberg et al. (2007) detected a higher short-term learning outcome for the so-called *hands-on* group. Additionally, Randler et al. (2011) found best scores for the learner-centered environment six weeks after the zoo visit. However, Abrahams and Millar (2008) as well as Wilde et al. (2003) did not find significant differences between several compared learning methods over longer time-scales.

Furthermore, there are many studies, which compare (constructivist) *student-centered* to (instructional) *teacher-centered* approaches within classrooms (e.g. Gerstner & Bogner, 2010; Heyne & Bogner, 2012; Randler & Bogner, 2006; Sturm & Bogner, 2008). However, the results of these studies were contradicting. Also, neither of them was focused on botanical gardens nor on a botanical topic. Our intention was to bridge this gap and to investigate the learning outcome as well as motivational differences of a teacher-centered compared to a student-centered approach at this particular informal environment.

The most often used educational methods in botanical gardens worldwide are guided tours, talks and lectures as teacher-centered methods, followed by student-centered interventions, like workshops or training courses (Kneebone, 2007). Approximately 20% of the botanical gardens evaluate their educational programs on the regular basis, with a focus on the effectiveness of the programs. Yet, they do so mainly by observations. Hence, the aim of our study is to investigate, whether often conducted student-centered workstations are more successful in teaching at a botanical garden (with regard to motivation and cognition) than teacher-centered workstations (similar to guided tours). Our student-centered workstations were designed on the basis of a constructivist approach. For the guided approach (instructivist) we used the same workstations, but involved a teacher instructing the students successively (see methods section). With this classification we follow the work by Heyne and Bogner (2012), although they called the guided approach *student-centered guided* or *guided learning at workstations*. The authors additionally made use of a third group, which was teacher-centered *sensu stricto*. In our study we omit this third group.

The student-centered workstations we developed adhere to the requirements of the three innate needs of the self-determination theory (SDT, see above), which should foster learning and retention (Randler et al., 2011): competence (Harter, 1978; White, 1963), relatedness (Baumeister & Leary, 1995) and autonomy (deCharms, 1968; Deci, 1975). In our approach, a student in a student-centered group may act depending on its competence, while working in a small group, and simultaneously interact with around two to four group members. Another attribute of the student-centered learning method is that the students can freely decide about the order, in which they work on the stations, and determine the working time needed for each station. Thus the students are comparably autonomous – they can conduct all trials by themselves and may decide, whether they want to gain knowledge via texts, images or originals (plants). All these attributes stand in contrast to the teacher-centered workstations we developed, where the students had to follow the teacher's order and speed. Furthermore, the teacher showed trials and images during his talk for a bigger group of 13–18 students. The teacher-centered workstations do not meet the requirements of the self-determination theory and should lead to lower motivational values and consequently to lower cognitive achievement. In general, we hypothesize:

1. Students, who participate in the student-centered workstation program, show higher motivation than those attending the teacher-centered program.
2. The student-centered workstations lead to higher cognitive outcome than the teacher-centered workstations at the out-of-school learning setting botanical garden.

Gender effects at out-of-school learning settings

Recently, some studies support the hypothesis that females prefer learning about botany, when compared to males (Fančovičová & Prokop, 2011; Hong, Shim, & Chang, 1998; Prokop, Prokop, & Tunnicliffe, 2007). Following from this we expect females to achieve higher cognitive scores than males, caused by a higher emotional preference of females for plants. This phenomenon is usually traced back to the evolutionary history of humans. Once, females predominantly were gatherers (Kaplan, 1996), whereas males went hunting. Thus, females are expected to be more attracted to plants. To our knowledge, with respect to the teaching method, neither males nor females showed any preference for student or teacher-centered approaches in previous studies (Meissner & Bogner, 2011; Randler & Bogner, 2006). Based on these results and the evolutionary psychology hypothesis we develop a third hypothesis for our study:

3. Females taking part in the intervention at the botanical garden show a higher learning outcome in both intervention groups because they are more motivated than males.

Methodology

Student sample

In summer of 2011 altogether 404 eighth grade students with an average age of 14.1 years from 14 Bavarian middle schools, so called ''Realschule'' (RS) and ''Mittelschule'' (MS), took part in this study. 229 of them were males and 175 were females. These students complete their school career at 10th grade and achieve a mid-level graduation. However, there are differences between the two school types. At the ''Mittelschule'' physics, chemistry and biology are covered in one subject, at the ''Realschule'' every field is a subject for itself. However, the contents are generally similar from the fifth to the eighth grade. Except for 57 individuals, all of the students visited the botanical garden of the University of Würzburg for one day. Those who did not formed the control group (C). The participating students were divided into a teacher-centered group (T, $n = 169$) and a student-centered group (S, $n = 178$), with respect to the intervention type. Always one class was assigned to one of each groups. This assignment of classes to both treatments was randomly drawn.

Study design

Within our quasi-experimental approach, we followed a before–after/control-impact design (Randler & Bogner, 2009). A control group is necessary to test for potential external effects between the tests (Lienert & Raatz, 1998). To measure already existing knowledge about the topic, one week prior to the garden visit, all students had to answer a multiple-choice-test with 14 questions (two questions for each topic/work station) in school, the pretest (for example questions see Fig. 1). Immediately following the respective treatment, students of both teaching methods had to complete the same test (with a random sequence of questions) to account for the cognitive outcome (posttest). Long term learning (retention) was assessed seven weeks after the garden visit in school. The control group only got the questionnaires for two measurements, pretest and retention, without any instruction (Fig. 2).

For our analysis, we concentrate on the motivation and increase in knowledge of the students. This choice is due to our goal of maximizing learning success of students with respect to their current curriculum. Therefore it is necessary to either assess their knowledge or comprehension of processes and relations. The latter, however, is difficult to assess, but might offer an interesting extension of this study. Yet, to supplement the findings based on knowledge scores, we also assess the intrinsic motivation of students (see above). The combination of both measures allows for a proper comparison between the tested treatments.

Usually, Cronbach's α is calculated to assess the reliability of questionnaires (Drissner et al., 2010; Gerstner & Bogner, 2010; Scharfenberg et al., 2007). For reasons of completeness, we have thus also calculated this measure for the knowledge questionnaire results. We obtained values for Cronbach's α of 0.59 (pre test), 0.61 (post test) and 0.65 (retention). According to Lienert and Raatz (1998), values between 0.5 and 0.7 allow for the differentiation of groups. However, this measure shows severe weaknesses (especially as it provides no information about internal test structure, i.e. unidimensionality; for details and additional literature see Sijtsma, 2009). Therefore we extended the analysis of the quality of our questionnaire by applying a Rasch model using the R-package ''eRm'' (version 0.15; Mair & Hatzinger, 2007). We performed Andersen's likelihood ratio test (Andersen, 1973) and got no significant deviation from the assumption of a Rasch model being valid ($X^2 = 20.6$, $df = 13$, $p > 0.05$). Thus, the prerequisites of a Rasch model are met. This means that the items are to a satisfying degree powerful, unidimensional and not strongly correlated (Koller et al., 2012). Consequently, we can assume our questionnaire to provide

One of the function of the root hairs is …

☐ *… to release sugar.*

☐ *… to assimilate sugar.*

☐ *… to enlarge the surface area.* *(correct answer)*

☐ *… to reduce the surface area.*

Where does *Aloe vera* accumulate water?

☐ *In the flower.*

☐ *In the stem.*

☐ *In the leafs.* *(correct answer)*

☐ *In the root.*

How are the structures of a leaf called, which allow the plant to yield dioxygen and steam?

☐ *Leaf pores.*

☐ *Stomata.* *(correct answer)*

☐ *Closing splits.*

☐ *Steam cut.*

Fig. 1. A translated selection of exemplary questions of the knowledge questionnaire. Correct answers were originally not indicated.

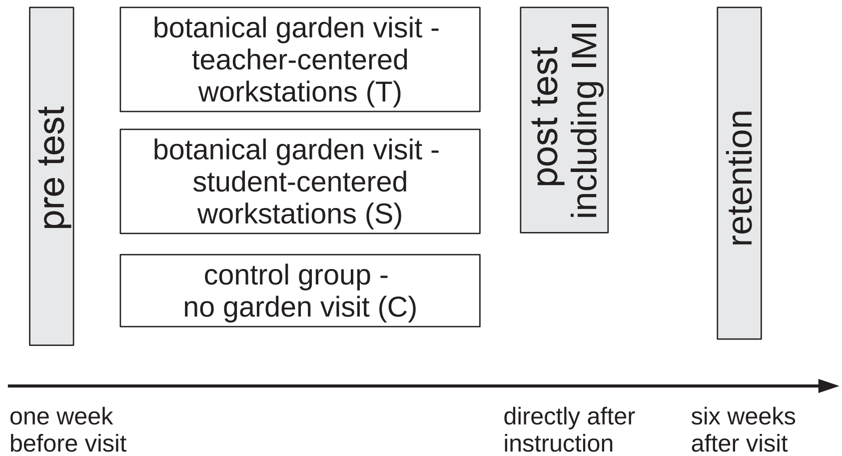

Fig. 2. Schematic representation of the study design. Performed tests are shown in gray, the arrow below denotes progression of time.

reliable results, which allow inference of the latent cognitive traits of the students. This also justifies working with the sums of knowledge scores for each student (see below).

Every participant of both groups received a workbook to save individual results. These workbooks were adapted to the teaching method: Whereas for the teacher-centered approach the books contained only questions regarding the stations, in the student-centered approach these questions were supplemented by working instructions. The program itself consisted of two lessons, with an overall duration of approximately 90 min. Following a short teacher-centered introduction concerning the plants' needs for water (approx. 30 min), the teacher (which was the same for all groups) also introduced the workbook, which was relevant for the success of the intervention (Sturm & Bogner, 2008). The teacher in our study was a pre-service teacher with biology as major subject, already holding a first state examination.

In case of the student-centered workstations, students were self-dependent and able to work free-choice according to the definition of *learning at workstations* (Gerstner & Bogner, 2010). They worked together in small groups of 3–5 individuals and decided, in which sequence they attended the six obligatory workstations. In combining the experimental materials, pictures and all the additional information at the workstations the students were able to answer the questions in the workbooks. One optional workstation was designed for fast and motivated learners. All seven workstations were independent of each other and covered the following topics:

(1) water absorption through root hairs (example: *Lepidium sativum* L.),
(2) water transport in vascular strands (example: *Apium graveolens* L.),
(3) root pressure (example: *Clematis vitalba* L.),
(4) transpiration (example: *Ocimum basilicum* L.),
(5) succulence (example: *Aloe vera* (L.) Burm.F. in comparison to *Plantago major* L.),
(6) adaptation to the habitat "pond" (example: *Nymphaea spec.*),
(7) optional: adaptation of *Tillandsia usneoides* L.

To avoid overcrowding of students at the stations, we placed several copies of instruction sheets and material at each station. After acting at the workstations the students compared their results to an answer booklet provided by the teacher after finishing work at all stations. Of course, the teacher answered additional questions.

In contrast to the procedure described above, for the teacher-centered approach one teacher led a group of approximately 15 students along a route covering the six obligatory workstations in the order of the listing above. At every workstation the teacher demonstrated trials, discussed the results and visualized the contents using illustrations, while the students were answering the questions in the workbooks to record the results.

Intrinsic motivation inventory

Immediately after the treatment twenty-three items of the intrinsic motivation inventory (IMI; Deci & Ryan, 1985, 1992) were delivered to the students, in combination with the knowledge questionnaire. Four sub-scales were integrated – tension, student's interest, perceived competence and perceived effort – each with a selection of five to seven questions. In accordance to Schaal (2006) we translated the items. The students had to choose between four categories for each statement: "not at all true", "somewhat true", "already true", "very true". Originally the IMI was intended for adults, but in the last years it has also been applied for fifth or ninth graders (e.g. Gerstner & Bogner, 2010; Sturm & Bogner, 2008).

Statistics

We used generalized linear mixed models (GLMM; Bolker et al., 2009), since the data we collected were nested and this method additionally allowed us to evaluate different hypotheses simultaneously. We used the sums of knowledge scores for analysis and thus assumed a Poisson error distribution, as we gathered count data (Crawley, 2007). Furthermore, as we have potentially influencing random factors, which are hierarchical, we defined student's identity nested in class nested in school place as random effects of the model. Treatment, test time (pre-, post-, retention-test), gender and school type were specified as fixed effects. To calculate the GLMMs we used the R language for statistical computing (version 2.15.0; R Core Development Team, 2012). To implement the models we used the "glmer" function from package "lme4" (version 0.999999). We initially implemented a full model with all possible interactions and performed model selection by means of the Akaike information criterion (AIC; e.g. Vatka, Orell, & Rytkonen, 2011). We also provide *p*-values based on Wald tests for the single explanatory factors of the resulting model. However, these values should not be overestimated, since model selection was still based on AIC comparisons – thus, the Wald tests were rather performed to estimate the influence of individual factors. Additionally, their calculation remains imprecise (Zuur, Ieno, Walker, Saveliev, & Smith, 2009). Due to the fact that the control group was only tested before and six weeks after the study time, we formulated two models. One model contained the two

Table 1
Results of a general linear mixed model with test time, gender, treatment and school type as fixed effects and code, class and school place as random effects. Shown is the final model resulting from AIC selection (Vatka et al., 2011; Zuur et al., 2009). The values for the different fixed effects categories are referenced to those not written in the table. *z*- and *p*-values result from Wald tests of the single explanatory variables.

Fixed effect		Regression estimate	*z*-Value	*p*
Category	Value			
Time	Pretest	−0.423	−12.18	<0.001***
	Retention	−0.180	−5.57	<0.001***
Treatment	Student-centered	0.007	0.11	>0.1
Gender	Females	0.004	0.12	>0.1
School type	Realschule	0.142	2.46	<0.05*
Time × Gender	Pretest × Female	−0.102	−1.86	<0.1
	Retention × Female	0.049	0.80	>0.1
Treatment × School type	Student-centered × Realschule	−0.157	−1.88	<0.1

* $p < 0.05$.
*** $p < 0.001$.

treatments (T, S) for all three times of measurement and another model additionally included the control group, but only for pretest and retention. For each of the four IMI sub-scales we constructed one GLMM including all questions of the particular sub-scale. Interaction-plots of the respective interaction terms from the resulting models were created for reasons of clarity.

Results

The students' knowledge about the topic *plants and water* increased significantly for both treatment groups following the instruction (Table 1). Their median knowledge score increased about five points for the teacher-centered workstation group (T) and four points for the student-centered workstation group (S; Fig. 3a and b). Only few students (17%) gained enough knowledge during the instruction to get a perfect score. Six weeks later knowledge of the students of both treatments decreased (Table 1), with a magnitude of approximately two points (Fig. 3b and c). In the pretest the control group (C) had shown slightly higher knowledge (Fig. 3a) compared to the other groups. Interactions were hence significant between the performed test (retention) and the treatment (control vs. teacher-centered, Wald test: $z = 4.477$, $p < 0.001$; control vs. student-centered, Wald test: $z = 4.560$, $p < 0.001$).

The interaction-plot in Fig. 4 shows that those students following the teacher-centered approach knew approximately one point more from the beginning until the end of the study in comparison to the students participating in the student-centered approach. However, both curves increase and decrease with a similar slope, thus showing that there was no effect of the treatment on learning outcome (note that this slight difference is not apparent in Fig. 3, as there only median values are plotted).

The final model contains an interaction between pretest and females (Table 1), indicating that female students performed slightly worse than males in the pretest, but not in the posttest (see also Fig. 5). The cognitive outcome of the females thus seems higher. Their scores increased by a value of approximately four following the garden visit, whereas the males' scores increased by three. Further, the females forgot less than the males from posttest to retention, but this interaction was fairly weak (Table 1).

Furthermore, students from the "Realschule" achieved significantly higher knowledge scores than students from the

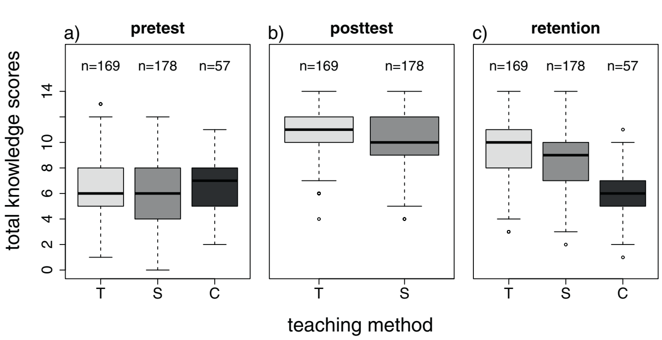

Fig. 3. Total knowledge scores of the two teaching methods and the control group ("T" = teacher-centered workstations, "S" = student-centered workstations, "C" = control group) for three measurements (a, b, and c). For the control group no data were collected at the time of the posttest.

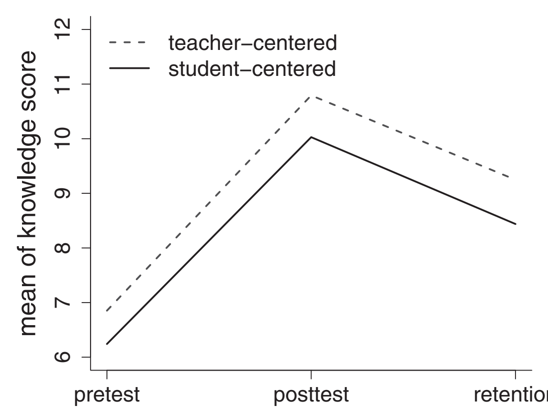

Fig. 4. Interaction between measuring time and treatment.

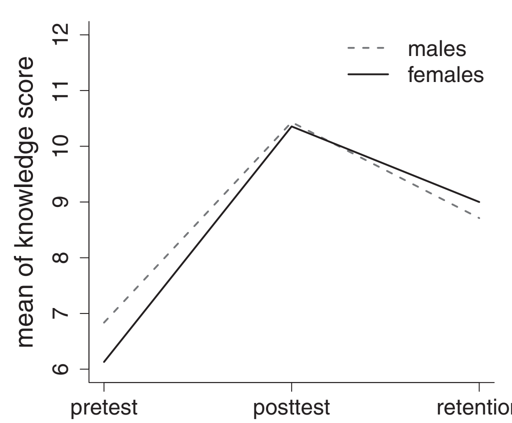

Fig. 5. Interaction between measuring time and gender.

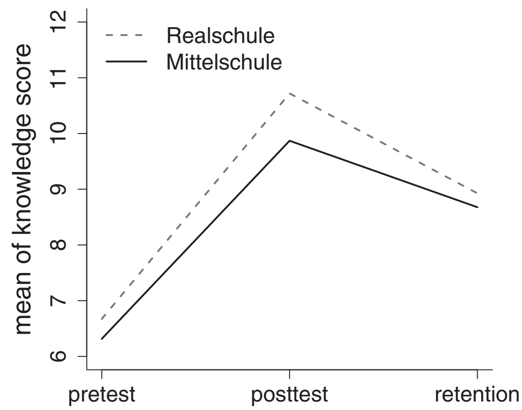

Fig. 6. Interaction between measuring time and school type.

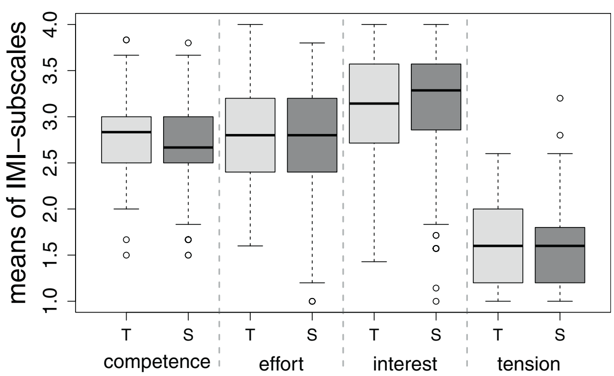

Fig. 7. Comparison of the means of the Intrinsic Motivation Inventory sub-scales ("competence" = perceived competence, "effort" = perceived effort) regarding to the two teaching approaches ("T" = teacher-centered workstations, "S" = student-centered workstations).

"Mittelschule". As Fig. 6 shows, the school types did not differ much between pretest and retention. However, the learning outcome after the instruction was higher for the students of the "Realschule" (one score). From the very beginning of this study the RS-students showed slightly higher scores for the teacher-centered approach, as can be seen in the negative regression estimate (−0.16). However, we detected no strong interaction between treatment and MS-students.

The interest of the students was high with a mean of three at a scale from 0 to 4 (no interest to high interest), even though the perceived effort was also high with a mean of three for both treatments (Fig. 7). However, the students apparently felt low tension and rated themselves competent for topic and activities. The students' intrinsic motivation was also indifferent within the two groups (T, S), thus being similar to the measured cognitive knowledge about *plants and water*. Between the two groups the means as well as the quartiles and the maximum and minimum values were almost equal. Hence, model selection for GLMMs for all sub-scales resulted in null models with no significant effects remaining.

Discussion

Teacher- vs. student-centered workstations

Concerning our first hypothesis the students showed no higher intrinsically motivated preference for the student-centered approach. In fact, their motivation was equally high for both treatments. This result stands in contrast to Sturm and Bogner (2008). The authors found a higher overall motivation for their student-centered group regarding interest and well-being (see also Schaal & Bogner, 2005).

Generally, the IMI scores of our study are comparable to the scores of other studies at out-of-school settings (Meissner & Bogner, 2011; Sturm & Bogner, 2010), even though participants there were confronted with five optional categories. We assumed the signal to be more clear if the students can only choose between four categories. However, they nevertheless tended to favor the two middle scores (except for the interest sub-scale, see Fig. 7).

The second hypothesis we had formulated in the introduction cannot be confirmed by our results. The student-centered approach was as good for the cognitive outcome of the participants as the teacher-centered one. Both treatments resulted in a higher knowledge score for a short and a longer time frame after the garden visit. Our results go in concert with the study of Wilde et al. (2003) and additional research focused on laboratories (reviewed in Abrahams & Millar, 2008; Hofstein & Lunetta, 1982, 2004), as these could also not reveal any significant differences between teacher- and student-centered approaches. However, Randler et al. (2011) found that the teacher-centered method was more effective with respect to the short-term learning outcome, although six weeks later the knowledge of the student-centered group was higher.

The fact that we could not detect higher intrinsic motivation for student-centered workstations may act as an explanation for a missing difference in cognitive outcome. As Ryan and Deci (2000) have clearly stated, only intrinsic motivation provides the means for the successful learning of students. Generally, the comparably high motivation we measured might very well be a consequence of the diverse and stimulating learning environment, which can be found in a botanical garden. This supports previous results on the positive effects of out-of-school settings on motivation and cognition (Drissner et al., 2010; Storksdieck, 2006).

Successful learning at student-centered workstations requires certain abilities of students regarding cooperative and self-determined behavior (Schaal & Bogner, 2005). However, nowadays in Germany most students rarely work under such conditions, although the German curriculum demands to facilitate such competences in school lessons. In everyday school life there is often no time and/or no material for such learning methods. Additionally, in the present study during the work at the stations the students were disturbed by gardeners and garden visitors. However, the teacher helped the students to keep their attention focused on the topic and the materials. The teacher in our study also spun a common thread through the teacher-centered workstations similar to a guided tour, which made the content logically easier to follow. The teacher showed the students how to solve the exercises and trials, too. They only had to concentrate on the content and on recording their results.

Thus, positive and negative effects of the two applied instructional approaches balanced each other, leading to an equal knowledge gain for short- and long-term learning outcome. As the long term cognitive results of our study were not very high with an increase of approximately two scores for both treatments, we suppose that the topic was too difficult and the intrinsic motivation of the students was not high enough.

With regard to the school type, the RS-students in the teacher-centered group achieved higher knowledge scores in the pre- and posttest, as well as in the retention, than the MS-students (Fig. 6). The fact that these higher scores were also observed in the pretest, leads us to the conclusion that it was based on a randomly biased sample. Those RS-students with the best scores were by accident accumulated in the teacher-centered group. This result shows the need for the pretest to avoid drawing false conclusions.

Gender effects

Our third hypothesis was that females should show a higher cognitive outcome and intrinsic motivation than males for a botanical topic. Indeed, in our study, females' seemed to profit more than males from the whole program, independent of the instructional approach. Yet, they were inferior to the males during the pretest. Except for the latter observation our results support the work of Fančovičová and Prokop (2011), which found higher knowledge of the females about plants for all of the three tests. However, we can also support Fančovičová and Prokop (2010) study on attitudes. Similar to their conclusions, there are no differences in the motivational preference for a botanical topic between genders, based on our results regarding the IMI, although it stands in contrast to the evolutionary psychology hypothesis mentioned in the introduction. With respect to the treatment method we found no gender effects, which is in accordance to a series of studies (e.g. Meissner & Bogner, 2011; Randler & Bogner, 2006; Schaal & Bogner, 2005). In summary, there is no preference of either males or females for either the teacher- or student-centered approach.

Potential limitations and future prospects

It might be seen as a limitation that the two learning methods, we used – teacher-centered and student-centered workstations – do not differ greatly, i.e. do not drastically confront a constructivist with an instructivist approach. Yet, we are convinced that our design allows us to pinpoint the effects of an increased involvement of the teacher. By changing only this parameter, we can eliminate other potential influences.

However, a shortcoming of our study is that we do only measure direct knowledge increase. Although we expect knowledge scores in combination with intrinsic motivation to provide a good approximation of general learning success, results may differ, when deep understanding of processes or the transfer of knowledge would be measured. In this case, student-centered workstations might be of higher value. It will certainly be an interesting challenge to assess these factors in future studies.

As formulated in the introduction, field trips to botanical gardens as described in this paper might be able to induce affective and attitudinal changes of students toward plants. By using the intrinsic motivation inventory in combination with knowledge scores, we aimed to shed light on this process. However, as our study revealed equally high motivation for all students, we cannot draw any conclusions on affective or attitudinal changes, yet. More research will be necessary to fill this gap.

One very important factor for the success of a given intervention regards the competence and motivation of the teacher. In our study, teaching was conducted by a pre-service teacher, who already had achieved the first state examination. However, in many botanical gardens for example horticulturists conduct learning programs (Kneebone, 2007). We would expect variability in motivation and competence to be higher among these guides than among educationally trained personnel. The influence of the teacher's profession is certainly an important research topic for future studies.

Conclusions

Botanical gardens are as suitable as out-of-school learning settings for students of the lower secondary school as museums or zoos. The measured interest and cognitive outcome are similar to other studies. One of the main advantages of out-of-school settings is the chance for haptic and visual perception of an often difficult and theoretical topic regarding plants. Botanical gardens thus have the best chance of all out-of-school learning settings to counteract *plant blindness* (Wandersee & Schussler, 1999, 2001). Yet, only few botanical gardens evaluate the effectiveness of conducted programs comprehensively or in an experimental way (Kneebone, 2007). With our study we work on filling this gap by comparing teacher- and student-centered workstations at this out-of-school learning setting. Our results show that constructivistic elements foster the learning outcome of students, regardless of the degree of the teacher's involvement. Thus, botanical gardens provide a perfect setting to supplement and complement school instructions. Nevertheless, future studies could focus on a comparison between our type of teacher-centered learning against *traditional guided tours*, consisting of teacher's speeches and only informal educational opportunities without constructivist elements. Another important task within this research field is a comparison between the botanical garden as an out-of-school learning setting and the classroom.

Acknowledgements

We thank several anonymous reviewers for helpful comments on earlier versions of this manuscript. We are especially grateful for the cooperation of all students and teachers of our participating schools. We are very thankful to our colleagues of the botanical garden of the University of Würzburg. Special thanks to Tina Katzenberger for her assistance at the work with the school classes. The study was supported by the regional school ministries of lower Franconia.

References

Abrahams, I., & Millar, R. (2008). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education, 30*, 1945–1969.

Ackermann, P. (1998). Außerschulische Lernorte in der politischen Bildung [Out-of-school settings in political education]. *Politik und Unterricht, 24*, 3–6.

Andersen, E. (1973). A goodness of fit test for the Rasch model. *Psychometrika, 38*, 123–140.

Baumeister, R., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin, 117*, 497–529.

Bitgood, S. (1989). School field trips: An overview. *Visitor Behavior, IV*(2), 3–6.

Bogner, F. X., & Wiseman, M. (2006). Adolescents' attitudes towards nature and environment: Quantifying the 2-MEV model. *The Environmentalist, 26*, 247–254.

Bolker, B. M., Brooks, M. E., Clark, C. J., Geange, S. W., Poulsen, J. R., Stevens, M. H. H., et al. (2009). Generalized linear mixed models: A practical guide for ecology and evolution. *Trends in Ecology and Evolution, 24*, 127–135.

Crawley, M. J. (2007). *The R book*. West Sussex: John Wiley & Sons.

Dairianathan, A., & Subramaniam, R. (2011). Learning about inheritance in an out-of-school setting. *International Journal of Science Education, 33*, 1079–1108.

deCharms, R. (1968). *Personal causation*. New York: Academic Press.

Deci, E. L. (1975). *Intrinsic motivation*. New York: Plenum.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum.

Deci, E. L., & Ryan, R. M. (1992). The initiation and regulation of intrinsically motivated learning and achievement. In *Achievement and motivation: A social-developmental perspective* (pp. 9–36). New York: Cambridge University Press.

Drissner, J., Haase, H. M., & Hille, K. (2010). Short-term environmental education – Does it work? – An evaluation of the Green Classroom. *Journal of Biological Education, 44*, 149–155.

Fančovičová, J., & Prokop, P. (2010). Development and initial psychometric assessment of the Plant Attitude Questionnaire. *Journal of Science Education and Technology, 19*, 415–421.

Fančovičová, J., & Prokop, P. (2011). Plants have a chance: Outdoor educational programmes alter students' knowledge and attitudes towards plants. *Environmental Education Research, 17*(4), 537–551.

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) optimize cognitive learning at work stations? *International Journal of Science Education, 32*, 849–870.

Harter, S. (1978). Effectance motivation reconsidered: Toward a developmental mode. *Human Development, 1*, 661–669.

Heyne, T., & Bogner, F. X. (2012). Guided learning about drug prevention with low achievers in science education. *World Journal of Education, 2*(6), 1–12.

Hofstein, L., & Lunetta, V. N. (1982). The role of the laboratory in science teaching: Neglected aspects of research. *Review of Educational Research, 52*, 201–217.

Hofstein, L., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education, 88*, 28–54.
Hofstein, A., Nahum, L. T., & Shore, R. (2001). Assessment of the learning environment of inquiry-type laboratories in high school chemistry. *Learning Environments Research, 4*, 192–207.
Hong, J., Shim, K., & Chang, N. (1998). A study of Korean middle school students' interests in biology and their implications for biology education. *International Journal of Science Education, 20*, 989–999.
Kaplan, H. (1996). A theory of fertility and parental investment in traditional and modern human societies. *Yearbook of Physical Anthropology, 39*, 91–135.
Killermann, W., Hiering, P., & Starosta, B. (2011). *Biologieunterricht heute*. [Education in biology today]. Donauwörth: Auer GmbH.
Kneebone, S. (2007). *A global snapshot of botanic garden education provision – 2006* http://www.bgci.org/education/global_snapshot_edu_provis (20.02.13).
Koller, I., Alexandrowicz, R., & Hatzinger, R. (2012). *Das Rasch-Modell in der Praxis. Eine Einführung in eRm*. [The Rasch model in practice. An introduction into eRm]. Wien: facultaswuv.
Lienert, G. A., & Raatz, U. (1998). *Testaufbau und Testanalyse*. [Test construction and test analysis]. Weinheim: Psychologie Verlags Union.
Mair, P., & Hatzinger, R. (2007). Extended Rasch modeling: The eRm package for the application of IRT models in R. *Journal of Statistical Software, 20*(9), 1–20.
Meissner, B., & Bogner, F. X. (2011). Enriching students' education using interactive workstations at a salt mine turned science center. *Journal of Chemical Education, 88*, 510–515.
O'Brien, L., & Murray, R. (2007). Forest School and its impact on young children: Case studies in Britain. *Urban Forestry and Urban Greening, 6*, 249–265.
Prokop, P., Prokop, M., & Tunnicliffe, S. (2007). Is biology boring? Student attitudes towards biology. *Journal of Biological Education, 42*(1), 36–39.
Randler, C., & Bogner, F. X. (2006). Cognitive achievement of group-based hands-on identification training. *Journal of Biological Education, 40*, 161–165.
Randler, C., & Bogner, F. X. (2009). Efficacy of two different instructional methods involving complex ecological content. *International Journal of Science and Mathematics Education, 7*, 315–337.
Randler, C., Kummerer, B., & Wilhelm, C. (2011). Adolescent learning in the zoo: Embedding a non-formal learning environment to teach formal aspects of vertebrate biology. *Journal of Science Education and Technology, 21*, 384–391.
R Core Development Team. (2012). *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing http://www.R-project.org/ (13.05.12).
Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*, 68–78.
Schaal, S., & Bogner, F. X. (2005). Human visual perception – learning at working stations. *Journal of Biological Education, 40*, 2–7.
Schaal, S. (2006). *Fachintegratives Lernen mit digitalen Medien*. [Content integrated learning with digital media]. Hamburg: Verlag Dr Kovac.
Scharfenberg, F. J., Bogner, F. X., & Klautke, S. (2007). Learning in a gene technology lab with educational focus: Results of a teaching unit with authentic experiment. *Biochemistry and Molecular Biology Education, 35*, 28–39.
Sellmann, D., & Bogner, F. X. (2012). Climate change education: Quantitatively assessing the impact of a botanical garden as an informal learning environment. *Environmental Education Research* http://dx.doi.org/10.1080/13504622.2012.700696.
Sijtsma, K. (2009). On the use, the misuse and the very limited usefulness of Cronbach's alpha. *Psychometrika, 74*, 107–120.
Storksdieck, M. (2006). *Field trips in environmental education*. Berlin: Berliner Wissenschafts-Verlag.
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*, 941–959.
Sturm, H., & Bogner, F. X. (2010). Learning at workstations in two different environments: A museum and a classroom. *Studies in Educational Evaluation, 36*, 14–19.
Vatka, E., Orell, M., & Rytkonen, S. (2011). Warming climate advances breeding and improves synchrony of food demand and food availability in a boreal passerine. *Global Change Biology, 17*, 3002–3009.
Wandersee, J., & Schussler, E. (1999). Preventing plant blindness. *The American Biology Teacher, 61*, 82–86.
Wandersee, J., & Schussler, E. (2001). Toward a theory of plant blindness. *Plant Science Bulletin, 47*, 2–9.
White, R. W. (1963). *Ego and reality in psychoanalytic theory*. New York: International Universities Press.
Wilde, M., Urhahne, D., & Klautke, S. (2003). Unterricht im Naturkundemuseum: Untersuchung über das richtige Maß an Instruktion [Teaching at natural history museums: A research about the optimal degree of instruction]. *Zeitschrift der Didaktik der Naturwissenschaften, 9*, 125–134.
Willison, J. (2006). *Education for sustainable development: Guidelines for action in botanic gardens*.
Zuur, A. F., Ieno, E. N., Walker, N. J., Saveliev, A. A., & Smith, G. M. (2009). *Mixed effects models and extensions in ecology with R*. New York: Springer.

Franziska Wiegand is a research associate and lecturer in the section Didactics of Biology at the University of Würzburg. She is interested in the development and evaluation of methods that improve teaching and learning in out-of-school environments, especially in botanical gardens. She also gives undergraduate courses in teaching in- and outside of classrooms. Being a trained nature educator she has a further focus on acquainting school children with nature.

Alexander Kubisch is a postdoctoral researcher at the Field Station Fabrikschleichach of the University of Würzburg. His research is focused on the theory of the eco-evolutionary dynamics of dispersal. He uses individual-based modeling techniques. Further he gives courses in advanced statistics.

Thomas Heyne is the director of the section Didactics of Biology at the University of Würzburg since 2008. He teaches undergraduate students in effective natural scientific teaching with regard to their later profession as teachers. The major foci of his research are the development, implementation and evaluation of the effectiveness of environmental and drug prevention programs for adolescents.