World Journal on Educational Technology

Vol 4, issue 2 (2012) 113-125

www.world-education-center.org/index.php/wjet

Outdoors and Online – inquiry with mobile devices in pre-service science teacher education

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Received July 03, 2012; revised July 29, 2012; accepted August 12 , 2012

Abstract

This study presents first findings about the development of an inquiry-based approach in pre-service teacher training. After reports of students who felt ill equipped to teach adequately about biodiversity, an inquiry-based learning course about biodiversity was created, using new technologies and an autonomous and collaborative learning environment. Compared to the traditional university course, research showed advantages in motivational and cognitive areas within the students tested.

Keywords: Inquiry-based learning, fieldwork, guided Inquiry, mobile learning, self-determination, biodiversity, computer-supported learning;

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1. INTRODUCTION

Biodiversity is considered an integral part of the biology curriculum in schools. Appreciation of biodiversity and associated ecological aspects can be achieved through an in-depth education about biodiversity issues. This kind of education is not easily achieved. Teaching about biodiversity in a holistic manner also includes aspects of socio-economic and ecological problems, thus complicating the training of teachers, who need a corresponding education as well. The importance as a topic calls for a balanced and varied approach to teaching, using methods that inspire the students.

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Menzel and Bögeholz (2009) highlight the need to “enhance sensitivity towards the […] species […] on a local scale” (p. 444). Achieving this kind of sensitivity towards biodiversity issues is in the hands of the teachers, putting today’s biology teachers at the frontline of these educational needs.

However, pre-service teachers feel ill equipped to teach about complex issues like this, due to their own education at the universities (Lindemann-Matthies et al., 2011). If this education is rudimentary and lacks connections to science didactics, pre-service teachers are not able to adequately teach biodiversity after the completion of their studies. This ability is a combination of subject knowledge about biodiversity and pedagogical content knowledge about methods to successfully teach about biodiversity. Pre-service teachers need specific courses that introduce them concepts that would enable successful teaching, as well as a good base of scientific knowledge.

Research shows that inquiry based learning can contribute to a successful lesson about biodiversity. Especially the combination of experiences within outdoor field activities and active, participatory and collaborative learning methods showed evidence to improve biodiversity knowledge and attitudes (Ramadoss, 2011, Orion, 2003). In order to teach about these aspects of biodiversity in a successful manner, teachers need to draw connections to their students’ life and interests using multiple methods to create a meaningful learning environment. Acquiring these skills in teaching seems to be difficult for pre-service science teachers (Lindemann-M. et al., 2009, Dikmenli, 2010). Teacher education therefore has to incorporate aspects of these professional problems, preferably using methods that are also suitable for the use in schools later on. If teachers are required to teach about local biodiversity for example, they should be trained to do so by their institution. Since teaching about complex systems is difficult at best, pre-service teachers can benefit from learning successful methods by experiencing them during their education. Science educators have suggested using a twofold approach to teaching, the so called “pedagogical double-decker” (Wahl, 2001): In order to confidently use inquiry-based approaches, pre-service teachers are taught about biodiversity with the same methods they later need.

Another promising approach to teaching in an open setting is the use of technology to present additional and supporting information. New technologies can be used to support self-determined learning (Ulbrich et al., 2010) which has been deemed a promising addition (Specht & Ebner, 2011). Mobile technology finds a special place in these new approaches. Devices can be used as a navigational tool as well as a source of information. Being able to access supporting information during field trips instantly can then support effective learning on site. Mobile and location-based learning could thus be helpful to combine the contextual learning about local biodiversity. This includes the personal engagement during self-directed learning activities and the young people’s every-day experiences with mobile technologies (cf. Kulska-Hulme & Traxler, 2007).

Especially teaching about biodiversity has quite a few methodological possibilities, ranging from open structured inquiry based learning to technology supported field trips. The various aspects that can be related to biodiversity create a plethora of topics to choose from in order to create an inquiry based setting. In this paper, we describe an approach to incorporate these possibilities into teacher education in order to enable the use of such methods in schools.

1.1. Teaching Biodiversity through Inquiry

1.1.1 Inquiry-Based Science Education

The complex nature of natural sciences has been a challenge to teachers across schools and university. Simple teaching of known facts did not yield the expected outcome of confident students that know about, and know how to do science. The inquiry-based approach to Science Education (IBSE) is based on a moderate constructivist's view that active engagement with scientific topics in a supportive learning environment helps students to develop a sound base of subject and process knowledge. IBSE encompasses a range of methods that are generally problem based. This means, that student's' inquiry is triggered by any kind of question. These situations emerge through creating problems, case or research scenarios, experiential or laboratory settings that are presented to the students to work on either in groups or autonomously. The structure of these settings, as well as the level of guidance can vary according to the capability of the participants (cf. Asaya & Orgill, 2010, Minner et al., 2010). Mui and colleagues (2011) especially highlight the importance of collaboration during inquiry-based science education. So and Ching (2011) emphasize the importance of authentic and active learning processes during thinking and talking about science cooperatively. All IBSE approaches share the aspect of inquiry as the main theme that allows the students to become researchers rather than recipients of a scientific topic, thus creating increased interest and motivation in the students.

In general IBSE is three tiered: In an IBSE situation, students would have a (i) phase of using their abilities to do science, (ii) phases of making up their meaning of scientific inquiry and a (iii) phase of learning the actual scientific content. If this IBSE situation is successful, students will be able to act, more or less, as scientists do in realistic situations. Since scientific capabilities and analytic thinking are highly sought after, students acquire key skills during their biology classes. These situations have to be facilitated by the teacher. The goal of teacher education should therefore encompass the ability to use IBSE related methods in the classroom.

1.1.2 The Inquiry-Based Biodiversity Teaching (InquiBiDT) approach

To create an environment that enables pre-service teachers to learn successful approaches to teaching, the actual outcome of their training has to be evaluated. Since several years, alternative approaches to biodiversity teaching have been developed and evaluated at the Ludwigsburg University of Education, combining collaborative, computer-supported learning environments with self-determined outdoor learning (Schaal & Randler, 2004; Schaal, 2009). The InquiBiDT approach is based on this former research and it uses an alternative form of university course about plant biodiversity based on IBSE. Subject matter and process knowledge can be acquired using inquiry-based learning strategies, supported by recent technology such as smartphones, wiki-platforms and other ICT tools. The course is divided into three parts that use a common inquiry structure like gathering information, developing process knowledge, and presenting results:

- Introductory Stage: The students receive a classic introduction to the kingdom of plants and relevant plant families, before they consolidate this knowledge in computer-supported collaborative learning environment and a visit to a botanical garden. Following the jigsaw-method (Aronson & Patnoe, 2011), up to six students are assigned to a 'segment group' that revisits a predetermined set of plant families and later rearrange into six 'jigsaw groups' that are assigned to a specific habitat around Ludwigsburg.

- The segment groups prepare an overview of their specific plant families as a segment of the whole plant system. Their results are represented in a digital mind map as hierarchically structured repository. The students' self-generated information base is supervised by the lecturers to be used later on in the botanical garden where the students expand their already acquired knowledge collaboratively and self-determined. After the initial learning in segment groups, the jigsaw groups form to distribute the experts evenly into new groups. Within the jigsaw groups now all specific plant families are represented by at least one expert of the specific segment group. These jigsaw groups map their assigned habitats using Google Maps and create a wiki about the biodiversity they find there. This wiki site is non-public at this stage and it can only be visited if the specific web address is known. According to Janssen and colleagues (2007) the wiki use explicitly makes students' participation visible within the learning process. This could become an incentive to invest more effort into the collaborative construction of information about the jigsaw groups' habitat. After uploading information about the species, the link to the specific habitat wiki site is translated into a QR-code and each habitat group hides the QR Code within a geocache directly in the habitat to be used by other visitors. The exact position of all geocaches is published in a specific Google Map as GPS coordinate. If someone discovers a geocache, the QR code can be decoded with a smartphone and the user is forwarded to the specific wiki site. In this introductory stage, the students conduct scientific inquiry activities by learning about the plant kingdom, how to identify plant families and subsequently the species outdoors. If needed, they request the lecturers' support by using the mobile devices for instant information and help during the field trips. They also communicate their results, using adequate electronic devices and software.

- Exploratory Stage: The jigsaw groups use their knowledge about their habitats and plant morphology to discover the biodiversity in the habitats of the other jigsaw groups. They use the GPS coordinates as well as the Google Map to find all habitats, survey the plant biodiversity and finally use the geocaches to get further information or to compare their results with the results of the group which provided the habitats' information. The QR code is the only way to access the habitats' information and thus a field trip to the specific places is obligatory. Using geocaches on the one hand inserts some motivating, game-like activity into the learning process. On the other hand it ensures getting students to the field trip without providing external control. During this stage, the students might also identify further species of plants that occur at the site, completing the survey of plant biodiversity at selected sites. In this stage the students discover plant biodiversity on their own, having practiced this in the botanical gardens and their habitat beforehand. Based on their knowledge of species they can also contribute to the survey and understanding of the biodiversity in different habitats.

- Results of the IBSE process: Stages 1 and 2 produce a collection of open access and location-based information about local plant species. The visits to other habitats in their small jigsaw groups increases the students' self determination of the learning experience who are independent of the time and space constraints of a larger group. Additionally, all students summarize the information (photo, location) about species they found in their digital herbarium. Some examples in German language can be found at http://wikis.zum.de/inquibidt.

2. METHODOLOGY

2.1 Purpose of the study

The main goal of the study is to investigate the cognitive, motivational and attitudinal effects of the InquiBiDT approach in pre-service teacher training. In detail the following hypotheses should be verified:

1. The InquiBiDT learning environment is equal to other well-proven approaches in regard to cognitive and motivational outcome.
2. The InquiBiDT approach increases the teaching attitudes of pre-service teachers to use inquiry-based and outdoor approaches later on in their biology classes.

2.2 Procedure

The study was realized as quasi-experimental field research in pre-post-test design (see table 1) in regular lectures at the Ludwigsburg University of Education (southwestern Germany) during the spring/ summer 2011.

The lectures in biodiversity are mandatory for every student aiming for teaching certificates; participants were randomly assigned to three different courses, one classic lecture (course 3), one self-determined but pre-structured (course 2), and one InquiBiDT course with an autonomous setting. Course 2 is a recent "best practice" for teaching plant biodiversity (cf. Schaal & Randler, 2004; Schaal, 2009). The InquiBiDT course is compared to course 2 and it just differs in the use of the mobile devices. As consequence the amount of jigsaw groups' self-determination within the field-work is higher. InquiBiDT course students work in their small jigsaw groups independently while course 2 jigsaw groups went to each habitat together. Providing relevant location-based information in the InquiBiDT course was realized using the wiki while students in course 2 used personal communication and small presentations in the field. According to Randler and Bogner (2008) course 3 dealt as control group, all courses were taught by the same lecturer.

Table 1. Overview of the study (number of students for each course indicated in brackets)

Pre-test	Concept Mapping of previous knowledge, teaching attitudes (TA), Intrinsic motivation Inventory (IMI) towards IBSE in biodiversity teaching		
Treatment (workload 3 ECTS)	**INQUIBIDT Course** autonomous-structured, cooperative, mobile technologies (N = 25)	**Course 2** self-determined, structured, cooperative (N = 36)	**Course 3** classic lecture (N = 28)
Post-test	Concept Mapping of previous knowledge, TA, IMI, computer-user self-efficacy (CUSE), computer experience (CE), structured interviews (9 per course → N = 27)		

For academic achievement within the field of plant biodiversity and taxonomy, a 30-minute concept mapping assessment was used (cf. Schaal et al, 2010). Within the concept mapping session, the students had to use 30 concepts (eg. Monocotyledonae, Rosaceae, single florescence) and 15 different relations (e.g. has net leaf venation, has tetragonal stipe) for concept map construction. The students' concept maps were compared to an expert concept map which was developed as an objective learning target by the authors. Furthermore, this expert map was validated by two other independent experts. The comparison to the expert map leads to a coefficient of correspondence, which spreads from -1 (completely negative of the student's map) to +1 (identical to student's map).

Student's perceived motivational aspects were assessed using the German translation of the Intrinsic Motivation Inventory (IMI) developed by Deci and Ryan (2011). As sub-scales (i) interest/ enjoyment, (ii) perceived competence, (iii) value/ usefulness, (iv) perceived autonomy, (v) effort and (vi) felt pressure and tension were used. The IMI scale was adapted according to the perception of IBSE in biodiversity teaching. Computer-user self-efficacy was controlled using the CUSE-scale, CUSE and IMI were also applied in previous research (Schaal, 2010).

For the analysis of the attitudes towards using IBSE for teaching biodiversity (TA) a questionnaire was developed, asking about teaching biodiversity (I) as lecture (e.g. "Learning biodiversity should be taught in a well-structured, teacher-centered environment"), (II) as self-determined and constructivist approach (eg. "Knowledge about biodiversity should be acquired as active inquiry") and (III) by using outdoor field-work (eg. "Knowledge about biodiversity can be efficiently achieved during active fieldwork"). Pilot testing of the scales revealed adequate reliability (Cronbach's α > .60 for any sub-scale).

Semi-structured interviews were used for triangulation of the quantitative results and for formative evaluation. Out of three groups with low, medium and high level of technological expertise, nine students per course were randomly selected. The questions covered the student's experiences with the learning environment, the technology, the peer-collaboration and the factor of time.

3. FINDINGS

3.1 Quantitative analyses of the questionnaires

The data was analyzed using IBM SPSS 19 for MAC. All data was either normally distributed or it was adequately transformed. Data analysis was carried out using t-test, ANOVA and analysis of covariance (ANCOVA).

Students of all courses achieved higher scores from pre- to post-test throughout the treatment (t-test: T69 >15.4, p < .001), pre- and post-test concept map correspondence were not correlated (Pearson R = -.10, p > .9). An ANOVA analysis revealed significant group differences in students' concept map correspondence after the treatment, while it did not differ before the intervention (see table 2).

Table 2. Means of concept map correspondence to an expert map

		Concept map correspondence	
Treatment	**N**	**Pre-Test Mean ± SD**	**Post-Test Mean ± SD**
InquiBiDT	25	-.82 ± .04	-.29 ± .20
Course 2	36	-.81 ± .07	-.34 ± .21
Course 3	28	-.82 ± .08	-.36 ± .23

Students within the InquiBiDT course reached the highest concept map correspondence compared to the learning target, followed by the students of course 2 and the lowest achievement was documented for the traditional lecture (ANOVA pre-test: $F_{67} = 0.1$, $p > .89$; post-test: $F_{74} = 3.9$, $p < .05$, $\eta^2 = .09$). This could be due to the fact that students had learned about the plant kingdom autonomously, which means they had to break down the information on their own.

Neither the CUSE nor the computer experience and the teaching attitudes differed in the three courses and therefore these scales were not respected for the further analysis.

The ANOVA analysis for the motivational variables revealed differences between the three courses just for the scales of perceived competence and value/ usefulness (ANOVA perceived competence pre-test: $F_{74} = 0.34$, $p > .91$; post-test: $F_{74} = 4.4$, $p < .05$, $\eta^2 = .1$. Value/ usefulness pre-test: $F_{74} = 2.1$, $p > .13$; post-test: $F_{74} = 3.4$, $p < .05$, $\eta^2 = .09$). In both categories, the InquiBiDt course students reported the highest values. This, points to the InquiBiDt course being a learning environment that increases the satisfaction of the learning experience. Especially the further increase in the scale value/ usefulness at already high general values for each course indicates that the students perceive the InquiBiDT course as an alternative and contemporary approach to their own learning and teaching about biodiversity.

Table 3. Means of perceived competence and value/ usefulness of the IMI scale
(5-scale Lickert, 1 = low value 5 = high value)

Treatment	N	Perceived competence		Value/ usefulness	
		Pre-Test Mean ± SD	Post-Test Mean ± SD	Pre-Test Mean ± SD	Post-Test Mean ± SD
InquiBiDT	25	2.3 ± .5	3.5 ± .7	4.1 ± .3	4.4 ± .4
Course 2	36	2.4 ± .6	3.1 ± .7	4.3 ± .4	4.2 ± .9
Course 3	28	2.3 ± .6	2.9 ± .6	4.1 ± .5	3.9 ± .5

The final model for the analysis of covariance (ANCOVA) consisted of the post-test concept map correspondence as dependent variable, the treatment was used as fixed factor and the perceived competence as well as the value/ usefulness were used as covariates. The results of the ANCOVA are presented in table 4 suggesting an influence of the treatment, the perceived competence, and the perception of usefulness of the learning activity on the post test concept map quality.

Table 4. ANCOVA with the post-test concept map correspondence, explained variance of the model $R^2 = .216$
(*$p < .05$, **$p < .01$, ***$p < .001$)

N = 89	**type III SS**	***df***	**Mean Square**	***F***	**Significance**	**Partial η²**
Corrected model	.894	4	.223	4.963	,001***	.216
Treatment	.347	2	.173	3.850	,026*	.097
Perceived competence	.405	1	38,15	9.000	,004**	,111
Usefulness/ value	.256	1	9,98	5.693	,020*	,073

3.2 Qualitative analyses of the interviews

The interviewer, who conducted the semi-structured interviews, was trained for the study and provided assistance to the respondents if necessary. The interviews dealt with questions about the physical learning environment (e.g. ”In your opinion, at which site was your learning process the most effective?”), about the use of technology (e.g. “To what extend did the technology, like GPS or mobile devices, support your personal learning process?”), about the factor of time (e.g. “During this course, which task was most time consuming?” or “Estimate the time you spent for the whole learning process in the course”) and about the peer-collaboration (e.g. “Which aspects of the collaboration within your working group were advantageous or obstructive?”).

The interviews were transcribed and then categorized by one person using the software MaxQDA. The categorization was randomly tested by another person and the inter-rater agreement was Cohen’s $\kappa = 0.7$. The qualitative results are presented in brief in the following list:

Physical learning environment: The respondents all highlighted the importance of fieldwork. Students of the courses 2 and 3 wanted to have more outdoor experiences while the InquiBiDT students did not openly require more. But the latter complained about the studies in the botanical garden, which they considered not to be effective. Students of the InquiBiDT course and the course 2 highlighted the self-determined fieldwork, which they perceived as very valuable. One student of the InquiBiDT course (INQ_2, lower computer experience) highlighted the potential of the geocaching activity as a mean for self-determined field work. Furthermore, the students of the InquiBiDT course stated that the fieldwork and the structuring of the information by use of a mind map would help them to memorize the plants and their taxonomy.

Use of technology: Students of all courses reported contradictory experiences depending on their personal technological skills. Experienced technology users easily applied the tools (Google Maps, Xmind for mind mapping, wiki) and devices (GPS receiver, digital camera), while the inexperienced students had to overcome some technical barriers and spent less time for “real learning” (INQ_3). Students attending the InquiBiDt course highlighted the potential of mobile technologies to get students to learn directly in the field.

Peer collaboration: Students of all courses emphasized the strength of cooperative and goal-oriented learning. Students attending the InquiBiDT course reported some problems with their collaboration but rated the concept of collaborative and self-determined learning as positive.

Time as factor: Altogether, the students spent between 40 and 60 hours of active learning time, with no differences between the courses.

4. CONCLUSION

The results of this study are largely in line with prior findings and theoretical assumptions. The pre-service teacher students were able to cope with the demanding challenge to organize their individual learning collaboratively. They were able to use the mobile technology for outdoor learning and they achieved similar or better results in comparison to the other students attending traditional university lectures about biodiversity. These findings are similar to the results of Ruchter and colleagues (2010), who used mobile devices for environmental education at a flood plain site and compared it to traditional instruments (brochures, personal guides). They also reported positive effects of mobile learning on environmental knowledge and motivation, especially for adult users. Using geocaches in combination with QR codes is a simple, low-tech approach for the construction of location-based learning environments to be used with mobile devices. But it still remains uncertain to what extend the game-like activity within geocaching activities contributes to students' learning motivation or interest, both should be core questions for further research dealing with location-based learning in biodiversity learning with mobile devices.

Payne (2009) described the successful use of wikis to support sustainability literacy. She highlights the potential to engage learners in active knowledge construction. One of the advantages of the InquiBiDt course was the collaboration in creating a wiki with relevant information. The students acted as learners and lecturers at the same time by processing and creating knowledge as a part of IBSE. Traditional courses do not require their students to access and edit knowledge collaboratively. Structuring and constructing information about local biodiversity provides an effective way to learn about it (cf. Makaris, 2010). Table 2 shows that the InquiBiDt course achieved the highest concept map correspondence. This result suggests that the collaborative way of different experts that work on a wiki is an effective tool for learning about a complex issue.

Furthermore, the wiki offers an easy-to-use tool to create location-based learning and information environment. This tool could be used in secondary school classroom and thus student teacher can easily transfer their own learning experience to create mobile learning environments for science education.

The results of the InquiBiDT course provide evidence that successful learning about biodiversity can happen in a less structured way than commonly held lectures. This includes active learning in the field as well as the above mentioned collaborative ICT use. This could be a way to give prospective teachers an actual experience of the desired outcome of fieldwork leading to knowledge about biodiversity. In this context Barrett (2007) described the importance of teachers' subjectivities concerning fieldwork to implement it in their courses. The effect of the InquiBiDT course showed in the student's professional self-esteem: The pre-service teacher students perceived the InquiBiDT course as useful; they felt more competent than the students in the other courses, making them more likely to use similar inquiry-based approaches to teaching in their own teaching career. Teaching attitudes towards using IBSE for teaching biodiversity did however not differ between the students of all courses. This finding is contradictory to recent research as the inclination to use IBSE methods should be higher in the students that attended the InquiBiDT course. This could be due to the fact, that students were contended with the teaching in general. Since the attitudes of the students were also assessed with a new tool, differences in the results could be due to changed specifications. The questionnaire assessing the student's attitude was pilot-tested, but large-scale validation is missing and further work to improve the scale is needed.

The interviews revealed the perception of a time consuming learning activity in all course students. Especially the InquiBiDT students with low technological affinity complained about the obstacles they experienced while using unknown technological applications. Using software for creating wikis, working with Google Maps or other open source tools needs to be practiced and if learners are not experienced to create digital content, these activities initially are less effective and take longer. Students with this handicap had to tolerate more frustration due to unsuccessful use of technology. This aspect has to be considered if mobile or any technology is used for IBSE. Another interesting finding is that only the courses 2 and 3 requested more fieldwork, while the InquiBiDT students were satisfied with the amount of fieldwork. Some of the latter wished for more faculty support during their field work activities. For future work it has to be considered, that this kind of support is provided for the first steps of self-determined learning and reduced subsequently during the IBSE activities.

In general, this pilot-study points towards the potential of the InquiBiDT approach to link IBSE to outdoor learning.

Acknowledgements

We are grateful to all student teachers that participated in the biodiversity courses and the study. Special thanks to Gabriele Topaltzis who uncomplainingly fed the computer with the students' numbers. The study was part of the project "The PATHWAY to Inquiry-Based Science Education" which is funded by the European Union in the 7th framework program "Science in Society", SiS-2010-2.2.1.1 no. 266624.

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