Case Study UniHB

for Teacher Students

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The European project INQUIRE

The EU FP7 INQUIRE Project (Inquiry based teacher training for a sustainable future) is a three-years project that focuses on inquiry-based science education (IBSE). 17 Partners from botanic gardens, science centre, natural history museums and universities from 11 countries participate in the INQUIRE project under the coordination of the University of Innsbruck in Austria. Educators of out-of-school learning environments and teachers of the primary and lower secondary level work together to develop INQUIRE courses focusing on biodiversity loss and climate change, the major global issues of the 21st century (http://www.inquirebotany.org).

The Institute of Science Education (IDN), Department of Biology Education, at the University of Bremen (UniHB) is one of the INQUIRE Partner institutes. It is responsible for pre-service teacher education in the secondary level. In addition, it is a school lab where ongoing teachers can gather their first experiences in planning, conducting and evaluating of school projects using the botanic garden and the green houses of the campus.

The INQUIRE courses in Bremen

During the first period of the INQUIRE project, the garden educators of Green Science Center botanika Bremen and the science educators of the Institute of Biology Education of the University Bremen, worked together in the development of the INQUIRE pilot course in Bremen. The course was conducted at the botanika. The educators of UniHB supported the botanika course with lectures about evaluation methods, IBSE activities and the adaptation of IBSE materials such as “Predators of the Plant Kingdom” (insectivore plants), which was based on a master thesis in biology didactics.

In the second period of the INQUIRE project, UniHB implemented the INQUIRE project in the pre-service teacher education. Science educators together with botanists of UniHB built a team and developed together the “INQUIRE Course for Teacher Students: Inquiry-based learning in the context of biodiversity loss and climate change”. The course was conducted in the labs, greenhouses and the University-intern biological garden. Therefore, the science educators cooperated with a garden educator of the Green Science Center botanika and botanists. The INQUIRE final course was offered to teacher students as well as active teachers. Two visits to the Green Science Center botanika Bremen and one visit to the Climate House in Bremerhaven were essential parts of the course. The Final INQUIRE Course was performed twice, in autumn (October 2012 – March 2013) and in spring (April 2013 – July 2013). Figure 1 gives an overview on the number of participants and pupils that were reached.

| Oct. 2011 – May 2012 | Initial INQUIRE Course together with Green Science botanika In-service teacher education course | 10 teachers 3 educators 1 science educator About 150 children |
| Oct. 2012 – March 2013 “INQUIRE for STUDENTS” | Final INQUIRE Course I – Autumn Course at the labs and green houses of the University Bremen Linking pre-service and in-service teacher education | 15 teacher students 4 teachers 2 science educators 2 botanists About 125 pupils |
| April 2013 – July 2013 “INQUIRE for STUDENTS” | Final INQUIRE Course II – Spring Course at the labs and green houses of the University Bremen Linking pre-service and in-service teacher education | 27 teacher students 4 teachers 2 science educators 2 botanists About 175 children |

Figure 1. INQUIRE Courses at Bremen
**Our understanding of IBSE**

We define scientific inquiry as a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in the light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations and predictions, and communicating the results. Scientific inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations by finding answers to questions (NCR 1995).

INQUIRE learning is not about memorizing facts – it is about working with living organisms (mainly plants), observing natural phenomena, formulating questions, linking evidence to explanations and finding appropriate solutions to explain observations and address questions and problems. There may be simple tasks or complex undertakings but they will always lead to learners experiencing the excitement of solving a question or problem on their own, usually as part of a team in a learning community (INQUIRE Consortium 2011).

**Professional Development in a Community of Learners**

Teachers’ professional learning starts with their pre-service teacher training and should continue through their whole working life. This lifelong learning enables teachers to act as experts in the profession of teaching in a world where scientific knowledge is permanently changing. To promote IBSE learning in an early stage of the professional development teacher students work together with active teachers in so-called Communities of Learners (CoLs) (Wenger, McDermott, & Snyder 2002). The CoLs are supported by science educators, botanic garden educators and botanists.

The term CoL is based on theories of situated learning (Lave & Wenger 1991) which describes the collaboration of teachers with each other and with researchers. CoLs are expected to improve learning and teaching skills, to share responsibility for professional growth, and to partake in professionally guided discourse about one’s own teaching and learning. The co-construction (Little, 1990) of IBSE activities and materials require agreements on the working processes, shared goals, as well as a critical rethinking of one’s own practice.

In addition teachers’ professional development depends on the teachers’ culture of reflection (Altrichter, Posch, & Somekh 1993). Action research is expected to support teachers in establishing a research relationship to their own practice (acting in the classroom) and to empower them to act as ‘reflective practitioners’ (Schön 1983).

According to Vescio et al. (2008) the following parameters of CoLs have proved to be important for the successful implementation and dissemination of new teaching and learning approaches (Elster 2010):

- Setting joint goals for the participants in the learning community
- Focusing on students’ learning (outcome orientation)
- Reflecting on curriculum, teaching and learning processes
- Focusing on collaboration
- Enabling teachers to understand themselves as learners
- Ensuring autonomy and freedom of decision-making
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Final INQUIRE Course “INQUIRE for Teacher Students”

The Bremen Final INQUIRE course was focused on teacher students and active teachers of the lower secondary level. The Six-Credit-Point course (180 hours) consisted of three modules: Investigation biodiversity and climate change, planning a school project and conducting the school project (see Figure 2):

Module 1. Teacher students and teachers acted as a “Community of Learners”. Supported by science educators and botanists they constructed knowledge in the context of biodiversity loss and climate change and built a shared understanding of IBSE together. They explored and investigated several IBSE activities using authentic learning environments: Outdoors, the green houses, the botanic garden and labs of UniHB as well as as at the Science Center Climate House.

Module 2. The participants built school teams consisting of one active teacher and three to four teacher students. The teacher students planned and conducted initial school visits to investigate the interest and knowledge of the pupils of “their” school classes regarding plants, biodiversity and climate change. Later on, in close cooperation with botanic garden educators and science educators the school teams developed 6-hour school projects. They developed IBSE activities and materials for 5-8 graders using an assessment check list with IBSE criteria as a guideline. Four questions steered the development of the school projects: How do we want to promote IBSE? How do we want to expand knowledge about the connection of biodiversity loss and climate change? What can we do to prevent plant blindness? What (else) shall our pupils learn?

Module 3. The teams invited their school classes and conducted the IBSE project at the biological garden (greenhouses) and the labs of UniHB. They evaluated and assessed the pupils’ learning and reflected on their own professional growth.

During the autumn course the teacher student teams developed and conducted five IBSE school projects, during the spring course the teacher student teams developed seven IBSE school projects. At the end, these projects were presented and discussed. A jury honoured the best project with a poster prize and all participants – teacher students as well as teachers - received INQUIRE certifications.
The course evaluation

During the complete process, the student teachers kept a research diary. They reflected alone or in their groups about their own learning, their ideas about IBSE, changes and further development of IBSE activities and materials, the effectiveness of their self-developed IBSE school project regarding the pupils’ learning. All these documents were gathered and put into group portfolios.

In addition, two master students evaluated the whole course on a meta-level. They used a mixed-method approach: Questionnaires for student teachers and teachers (pre-post-design), world cafés after each meeting, interviews with teachers and educators and the analysis of the group portfolios. In addition, an INQUIRE film was produced.

In the meantime, the meta-evaluation of the INQUIRE autumn course has been completed. The analysis of the spring course is still in progress. Therefore, the presented data is based on the findings from the autumn course only. In this course 15 teacher students and four teachers participated. They were supported by two science educators, one garden educator and two botanists.

Aspects and questions of research

According to Shulman (1986) teachers’ knowledge is characterized by subject knowledge (knowing about the subject content), Pedagogical Content Knowledge (PCK - knowing how to teach the content) and pedagogical knowledge (knowing how to teach more generally). Park & Oliver (2007) differentiate Shuman’s concept of PCK and define a hexagon-model on which we have based the Final INQUIRE Course evaluation (Figure 3).

Figure 3. Hexagon-model of Pedagogical Content Knowledge (Park & Oliver, 2007; changed)

The focus of the evaluation of the INQUIRE course Bremen are based on two levels:

1) Personal level: We investigated the professional development of the teacher students regarding their subject knowledge and their pedagogical content knowledge (Park & Oliver 2007).
2) **System level:** We investigated the “success” of the Community of Learners” (Vescio et al. 2008) and the implementation of the INQUIRE project.

**Findings**

1) **Personal level: Professional development of teacher students**

**Subject knowledge:**

“Today we learnt a lot about biodiversity. The different plants and their morphological adaptation to climate factors – that was new for me.” (diary_teacher student_C1)

Student teachers as well as active teachers reported an increase of **subject content knowledge** in the field of biodiversity (Figure 4). The educators at the biological garden, in the Green Science Center botanika and the Climate House were recognized as experts in their specific domain. The flat hierarchy between student teachers, teachers and educators supported a multi-faceted mutual learning.

![Subject knowledge about biodiversity](image)

**Figure 4.** Average scoring achievement of teacher students in the pre-post-test regarding factual knowledge about biodiversity

Based on the questionnaire survey (pre-test) we indicated that the teacher students had little prior knowledge about biodiversity and the connection of biodiversity loss and climate change. During the course the teacher students gained a more differentiated picture about the three dimension of biodiversity: Genes, species and landscapes. In the post-test 14 from 15 students reached level 3. They gained elaborated knowledge about the aspects and concepts of biodiversity (Figure 4).

“During this meeting I learnt that it is is wrong to say that biodiversity is decreasing, because there are a lot of species left which have not been discovered until now.” (diary_teacher student_A3)

“[…]biodiversity, I knew before that it is about the different plant and animal species different habitats and genetic diversity, I caught up on the meaning of the word “biodiversity” by reading, but I did not know how to implement this contents into my lessons before.” (interview_teacher)
The participants reported a constant increase in their level of knowledge about plants. They gathered detailed information about plants and their survival in the winter, plants and their pollinators, the diversity of certain plant families like Bromeliad, Orchid, and Rhododendrons.

“Rhodos (Rhododendrons), Rhodos, Rhodos – I didn’t know anything about their diversity before the INQUIRE project.” (diary_teacher student_C2)

“Plants in winter ... learning about their different strategies of survival has been interesting ...” (diary_teacher students_C2)

**Pedagogical Content Knowledge**

The development of an IBSE school project in teams, together with active teachers, promoted the Pedagogical Content Knowledge (PCK) of the participating teacher students and teachers. They gained knowledge about the pupils’ attitudes, knowledge and interest, knowledge about planning and conducting IBSE activities, knowledge about the curriculum, knowledge about unconventional assessment techniques like concept cartoons and concept maps. Some of the results regarding PCK are explained in more detail:

**Methodological knowledge about IBSE**

“I feel confident about planning and conducting IBSE activities.”

Based on the comparison of the tests in the pre-post design, we identified an increase of the self-estimation of the teacher students about their own IBSE competences. Based on the novice-expert-paradigm (Dreyfus & Dreyfus 1987) the teacher students moved from mainly “beginners” to “advanced” or “experienced” with regards to their competences in IBSE (see Figure 5).

![Self-estimation of IBSE competences](image)

Figure 5. The self-estimation of competences regarding IBSE in the pre-post comparison (N = 15 teacher students)

**Willingness to use inquiry-based learning approaches**

The participants reported an increase in practical knowledge on how to initiate and conduct IBSE processes. That led to a readiness to use inquiry-based teaching and learning approaches. The self-estimation of IBSE competences and the willingness to teach in this way arose.
“Especially exciting for me was to try out the teaching materials developed by us, because never before had I been confronted with such an open and research-oriented task.” (diary_teacher student_A12)

“…and when they can explore something on their own. This inquiry-based science education, is very different from just adopting something in a passive way. For me this was great.” (interview_teacher)

Most of the teacher students reported a commitment to the effectiveness of IBSE in the pre-test as well as in the post-test. Reasons they gave were “practical work”, “high interest”, “fun”, “motivation”, “less inert knowledge”, “scientific inquiry”. The number of teacher students who were willing to use inquiry-based learning approaches often increased from 1 (pre-test) to 10 (post-test; N = 15). (see Figure 6)

Figure 6. Willingness to use IBSE approaches (N = 15 teacher students)

“To me, inquiry-based science education means to train the cognition of the children corresponding to their abilities and to develop a holistic perspective on the children. Not to say, he is not doing good in maths, he will also have problems with other subjects, but let-him-try-out and see, if he has unknown abilities, see what comes out.” (interview_educator)

Inquiry-based learning in the school projects

“I realised that IBSE does not need to involve “hands on” activities, but there has to be an inspiring and stirring task like a “minds on” activity.” (diary_teacher student_C8)

“I learnt that IBSE activities can be created depending on the skills of the school class. Corresponding to the autonomy of the students the IBSE activities can be open, guided or completely structured. A combination or gradation is also possible. Yet, it is regarded for all gradations that the pupils get new insights by researching on their own.” (diary_teacher student_A4)

One of our goals was to describe a multi-faceted IBSE approach. We encouraged the school teams to plan and develop IBSE activities and school projects - according to the specific circumstances of the school classes – open, guided or structured. We showed different IBSE hands-on and minds-on
activities, mysteries, cartoons and mind maps and invited the school teams to choose or to develop the IBSE activities themselves on a level of openness they thought to be suitable for their school classes. Posters from the school projects (in German language) are in the appendix. Figure 7 shows three of the school projects of the Final INQUIRE Course in autumn/winter 2012/13. The composition of the IBSE elements “finding a research question”, “setting up hypotheses”, “collecting data”, “analyzing data”, “interpretation of evidences”, “connecting with (former) knowledge”, “communicating findings”, and “reflection” ranged from 0 (very structured) to 6 (very open).

Figure 7. Examples of IBSE activities / school projects “Plants in winter”, “Bromeliads”, “Mount Kinabalu”. 0 (structured) – 3 (guided) – 6 (open)
Would you like to visit botanic gardens?

“Would you like to visit botanic gardens with school classes in the future...?”

80% of the participants had experiences with out-of-school environments. These experiences could be gathered mainly during the own school time as a pupil. During their biology education study the teacher students visited the botanic garden infrequently.

“Our first destination led us to the greenhouses of the University Bremen. Although I will finish my master study soon, I have never been there. We got interesting information and I could “refresh” my botanic knowledge.” (diary_teacher student_C2)

Figure 8 gives an overview about the willingness of teacher students to visit botanic gardens in the future – together with their prospective school classes. The readiness increased during the INQUIRE course.

Figure 8. Willingness to visit botanic gardens together with school classes (N = 15 teacher students)

During the INQUIRE course the teacher students visited the Green School “botanika” twice. All participants reported on the visits in the botanic garden very positively.

“It was a very valuable experience to visit the authentic learning environment of the botanic garden “botanika”, because we could conduct and try out an IBSE teaching unit by ourselves.” (diary_teacher student_C2)

“I believe working with living organisms is more effective, than working with books and pictures, especially for younger pupils.” (teacher student)

„Firstly, it is an authentic learning environment that is more interesting for the kids than learning in the classroom, a place where they are everyday [...]. (interview_teacher)
**Willingness to reflect on teaching experiences**

*Which methods of reflection do you prefer?*

The student teachers were invited to reflect using a research diary, alone or in groups or during discussions in the world café. We differentiated between reflection-in-action and reflection-on-action (Schön 1987). Figure 9 demonstrates the change and increase in the willingness to reflect in different ways.

In general we recognized that the student teachers’ willingness to reflect on the course modules and on the teaching experiences increased during the INQUIRE course. We found different reflection approaches about IBSE within the research diaries.

“Furthermore I learned new methods of evaluation. I only knew questionnaires and interviews. The use of concept cartoons and concept maps for the evaluation of pupils’ concepts were new to me.” *(FT_Stud_C1)*

“Also interesting was the „World Café” at the end of every meeting, which was a very good opportunity to reflect on the relevant content and to exchange impressions of the seminar with the other participants.” *(FT_Stud_A5)*

![Figure 9. Possibilities of reflection in the pre-post-test (N=15 teacher students)](image)

In conclusion, the teacher students’ interest in self-reflection increased. 14 from 15 students ticked the box “interested” and “very interested” in self-reflection. This result was very surprising but we interpreted that the participants were successfully on their way to become “reflective practitioners”.

In addition the educators promoted their reflection competences, too:

“I have already evaluated [the project], because I have adapted contents of the INQUIRE project for my classes. [...]We always had meetings, where we discussed and reflected on what we did!” *(interview_educator)*
2) System level: Success of the “Community of Learners”

“The communication and the social skills are trained by working in a team.” (RD_stud_A7)

Figure 10 gives an overview on the subjective estimation of success of the Bremen Communities of Learners (data based on reflections after each meeting; 7-point-Likert-scales; % of agreement of very successful and successful).

Student teachers, teachers and educators successfully set up joint goals (especially in planning the IBSE school projects), focused on IBSE learning using check lists and by planning and testing IBSE activities. Student teachers reflected regularly on their experiences during the INQUIRE meetings by use of research diary writing. The participants understood themselves as learners. The atmosphere during the meetings was inspiring and allowed autonomy and self-efficiency of the participants.

The notices in the research diaries and the interviews showed that the team work had been very fruitful:

“I would even say, that this was the best working teamwork I did during my entire study time. Apart from the successful developed teaching unit and the portfolio, we got along with each other very well and that improved the group cohesiveness.” (RD_Stud_A7)

“Hence I like it very, very much to work together on a subject in a group. Great results emerge from the different impulses.” (Interview_teacher)
Conclusions

The Pilot INQUIRE Course, developed together with the garden educators and conducted in the Green Science Center botanika, was a successful in-service training. In the Final INQUIRE Course we wanted to cross boundaries by developing a course design that allowed us to link pre-service and in-service education. Teaching and learning according to IBSE needs a conceptual change and this can be performed more easily within a constructive learning environment. IBSE is a challenge for active teachers as well as for teacher students. Therefore, we promoted the establishment of Communities of Learners (CoLs), and we used action research methods (research diary writing, portfolio of evidence) to foster reflective learning. Action and reflection, exchange and networking in iterative circles should promote a process that we called “learning to teach by teaching to learn IBSE”.

Professional growth

Student teachers as well as teachers reported an increase of subject knowledge in the field of biodiversity, biodiversity loss and climate change and an increase of methodological knowledge and self-efficiency regarding IBSE. The flat hierarchy between student teachers, teachers and educators supported mutual learning. The development of an IBSE school project in union promoted the Pedagogical Content Knowledge (PCK) of the participating student teachers as well as of the active teachers. Scientists, as well as educators at the biological garden, the Green School botanika and the Science Center Climate House, were recognized as experts in their specific domain. The out-of-school environments offered authentic learning environments to discuss the importance of plants, aspects of endangered biodiversity and the responsibility of human beings for the natural environment. While promoting IBSE we wanted to show “a way of teaching and learning that is as colourful, sparkling and fascinating as nature itself”.

Pupils’ learning

Within both of the Final INQUIRE Courses, the participating teacher students developed 12 IBSE school projects within their school teams. Examples are “Plants in winter”, “How to plant a Rhododendron avenue?”, “Why do we need bees?”, “Does the increase of allergies have something to do with climate change?”, “Hummingbird seeks Bromeliad”, “Expedition to the Mount Kinabalu”, “On a photo safari at the botanic garden”, “Predators of the plant kingdom”, “Are bumblebees able to learn?”. The teacher students evaluated the pupils’ learning with pre-post questionnaires (4-point-Likert scales). The findings show that the IBSE school projects and the specific IBSE activities were of great interest and relevance to the pupils (95% score with “very interesting”). Their subject content knowledge about biodiversity and the understanding of the connection of biodiversity loss and climate change increased. In nine of the 12 projects we recognized actions of how to overcome plant blindness.

“The interest of the pupils was aroused by the real encounter with living plants and a small segment of a tropical rain forest.” (dairy_teacher student_A3)

“For me it was especially valuable that the material focuses on a subject of socio-cultural importance, which increases the interest of the pupils.” (dairy_teacher student_C9)
Implementation in the teacher education curriculum

In conclusion, the INQUIRE for Students course was an innovative teacher education course, linking pre-service and in-service education, linking science educators and scientists, linking school and university. The course had the potential to raise the value of authentic learning environments, learning outdoors, in botanic gardens and greenhouses and in science centers.

Based on its success and the satisfaction of the teacher students with the INQUIRE Course design, we decided to implement the “INQUIRE for Teacher Student” in the Bremen teacher education curriculum. In the future it will be an elective module within the master of education program of ongoing biology teachers of the secondary level (6 Credit points; 180 hours course). In addition it will be part of a module “Environmental education” for ongoing primary teachers (3 Credit Points; 90 hours course).

UniHB is very interested in keeping the contact to the Green Science Center botanic and the European botanic garden network. In addition, the educators of the Science Center Climate House and the educators of the Zoo by the Sea in Bremerhaven, are interested to become partners. We could find school partners, too, and make cooperation contracts with headmasters of six secondary schools in Bremer and Lower Saxony. The science teachers of these schools are interested in participating. These are all very good circumstances for continuing the INQUIRE courses in the future. All in all, the European INQUIRE project raised the standards of teacher education and promoted the curriculum reform at the University of Bremen.

“Summarized I think that the effort for the INQUIRE-project was really worth it, because I could gain a lot of new experiences and information from my participation.”
(dairy_student teacher_C9)

References


INQUIRE (Inquiry based Teacher Training for a sustainable future).


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Final INQUIRE Course – Autumn Course Participants

Final INQUIRE Course – Spring Course Participants

We thank all teacher students and teachers, garden educators, science educators and scientists for their cooperation within the INQUIRE Courses.