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Raising Standards through INQUIRE in Pre-service Teacher Education

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ABSTRACT: Raising standards through inquiry-based science education (IBSE) - what are the challenges for pre-service teacher education? What do ongoing teachers and active teachers learn from each other when planning, conducting and evaluating minds-on and hands-on IBSE activities in the classroom? What do they learn "beyond" IBSE? The Bremen teacher education course "INQUIRE for Teacher Students – inquiry-based learning in the context of biodiversity loss and climate change" aims to raise standards in teacher education using IBSE methods in an innovative manner. Science educators, botanists and botanic garden educators support Learning Communities of ongoing and active teachers in the development of IBSE school projects for students of the lower secondary level. The evaluation the course measures the professional growth of the participating teacher students regarding their PCK and subject knowledge, the successfulness of the Learning Communities and the implementation of the course in the regular teacher education program. The course is part of the European FW7 project INQUIRE (http://www.inquirebotany.org/en).

KEY WORDS: inquiry-based, IBSE, pre-service, teacher education

THE EUROPEAN PROJECT INQUIRE

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

The Institute of Science Education, Department of Biology Education (IDN-Bio), at the University of Bremen is one of the INQUIRE partner institutes. It is a pre-service teacher education institute for teachers of the primary and the secondary level. Within the INQUIRE project the IDN-

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Bio cooperated with the Green Science Centre Botanika Bremen and the Science Centre Climate House in Bremerhaven in the development of an innovative teacher training program for ongoing teachers at the last stage of their university study to become Master of Education. The 6-Credit-Credit-Point course was offered in the winter semester 2012/13 and the summer semester 2013 to promote IBSE in the context of biodiversity loss and climate change.

IBSE and beyond

Our understanding of IBSE is that of multifaceted activities: making observations; posing scientific questions; examining books and other sources of information to see what is already understood; planning investigations; reviewing what is already known in the light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations and predictions, and communicating the results (Linn, Davis and Bell 2004: 9). Scientific inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations by finding answers to questions (NCR 1995). In the context of the INQUIRE project IBSE 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

THE INQUIRE FOR TEACHER STUDENTS COURSE AT BREMEN

The course is addressed to teacher students and active teachers of the lower secondary level. Figure 1 gives an overview of the course.

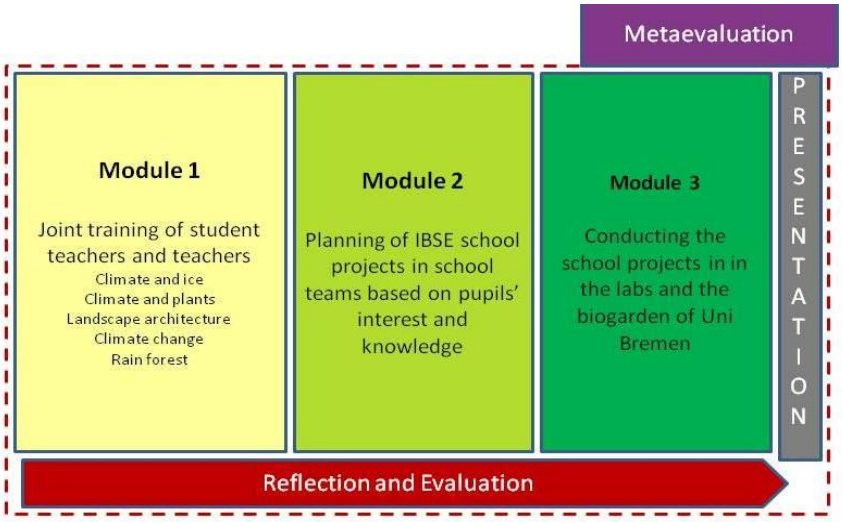

Figure 1. Schedule of the INQUIRE

The six-credit-point course (180 hours) involves three modules:

- **Module 1.** Teacher students, teachers, botanic garden educators, science educators and botanists build "Communities of Learners". Supported by science educators and botanists they construct knowledge in the context of biodiversity loss and climate change. They investigate different methods of inquiry based learning at authentic learning sites outside the classroom, in the green houses, in the botanic garden as well as in the Science Centre Climate House.
- **Module 2.** The participants constitute school teams consisting of one active teacher and three to four teacher students to develop and plan six-hours-lasting school projects with hands-on and minds-on IBSE activities for 5th to 8th graders.
- **Module 3.** The teams conduct the IBSE projects at the green houses of the biological garden and the labs of the Institute of Biology Education at the University Bremen. The teams evaluate and reflect about the pupils' learning and their own learning. In addition a meta-evaluation investigates the teacher students' professional growth and the implementation process.

RESEARCH QUESTION AND DESIGN

The focus of the evaluation of the INQUIRE course Bremen laid on the professional growth of the participants regarding their subject knowledge and Pedagogical Content Knowledge (PCK) according to Park & Oliver (2008) and on the successful implementation of the INQUIRE project based on Vescio, Ross & Adams (2008). Research questions in detail were:

1) Effectiveness of the course regarding the subject knowledge about biodiversity and climate change
2) Effectiveness of the course regarding
   a. IBSE teaching and learning;
   b. teaching and learning about biodiversity loss and climate change;
   c. knowledge about the curriculum;
   d. knowledge about assessment;
   e. knowledge about reflection about school experiences and the self-learning
3) Successfulness of the Learning Communities

In addition, the following four questions steer the planning and evaluation of school projects: In which way is the connection of biodiversity loss and climate change in the focus? In which way is IBSE promoted? What shall be done to prevent the so-called "Plant-Blindness?" What shall our pupils learn in the IBSE school project?

For the evaluation of the course we used qualitative and quantitative methods: research diaries of teacher students (Altrichter, Posch, & Somekh 1993), questionnaires (pre-post) for teacher students and teachers, structured interviews (pre-post) with teachers and World Cafes after each meeting.

With questionnaires (open questions) and guided interviews we gather data about the attitudes and knowledge of the participating teacher students and teachers regarding research question 1 and 2. For the acquisition of data about research question 3 we used closed questions.

For data triangulation of the questionnaire and interview data we used research diaries and the "World Café"-method.

The guiding questions for the teacher students' research diaries were about a) What did I learn about IBSE?; b) What did I learn about the connection of climate change and biodiversity loss?; c) Which elements will I select for planning my own IBSE school project; d) My further ideas.

The World Cafe was a communication platform to promote the so-called collective intelligence through constructive dialogues. This new method is based on the estimation that knowledge and creativity are essential part in the community but should be enriched by group dialogues (Schieffer, Isaacs & Gryllenpalm 2004). In the INQUIRE projects the group dialogues were about 1) the effectiveness of the course modules; 2) the irritations; and 3) the highlights.

The open items of the questionnaire and the interview transcripts were analysed according the paradigm of Qualitative Content Analysis (Mayring 2003). For the analysis of the closed items we used descriptive statistics and factor analysis (means, standard deviation, t-test, Cronbach's Alpha).

The Course INQUIRE for Teacher Students was conducted twice, in autumn/winter 2012/13 and spring/summer 2013. In total 44 teacher students and eight active teachers participated in the course. They were supported by two botanic garden educators, two teacher educators of the IDN-Bio and two botanists of the Institute of Ecology of the University of Bremen. The course participants developed 12 IBSE school projects for pupils of the lower secondary level. In total, 300 pupils we could reach.

FINDINGS AND IMPLICATIONS

Professional Growth

Student teachers as well as teachers reported an increase of subject knowledge in the field of biodiversity as well as an increase of methodological knowledge and IBSE (comparison of pre-post questionnaire). The educators at the biological garden, in the Green

Science Centre botanika and the Climate House were recognized and accepted as experts in their specific domain.

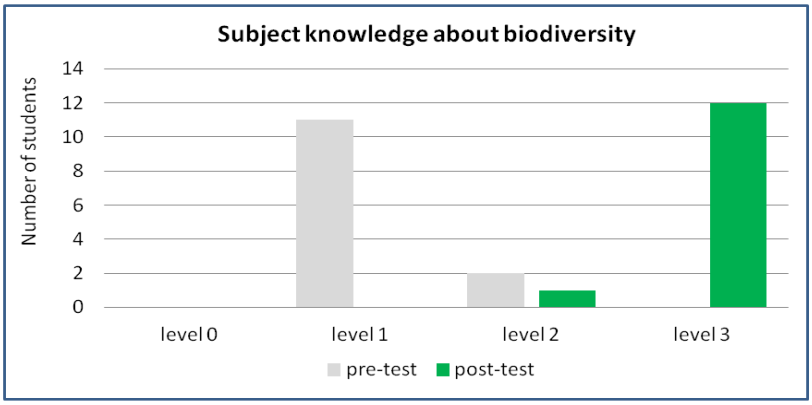

Figure 2. Average scoring achievement of teacher students in the pre-post-test regarding factual knowledge about biodiversity (N=15 teacher students, autumn course)

Based on the questionnaire survey (pre-test) we indicated that the teacher students had little prior knowledge about biodiversity. 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 2). In addition they reported about a constant increase in their level of knowledge about plants species. 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.

We identified an increase of the self-estimation of the teacher students about their own IBSE competences ("*I feel confident about planning and conducting IBSE activities*."). Based on the novice-expert-paradigm (Dryfus & Dryfus, 1987) the teacher students moved from mainly "beginners" to "advanced" or "experienced" with regards to their competences in IBSE (see Figure 3).

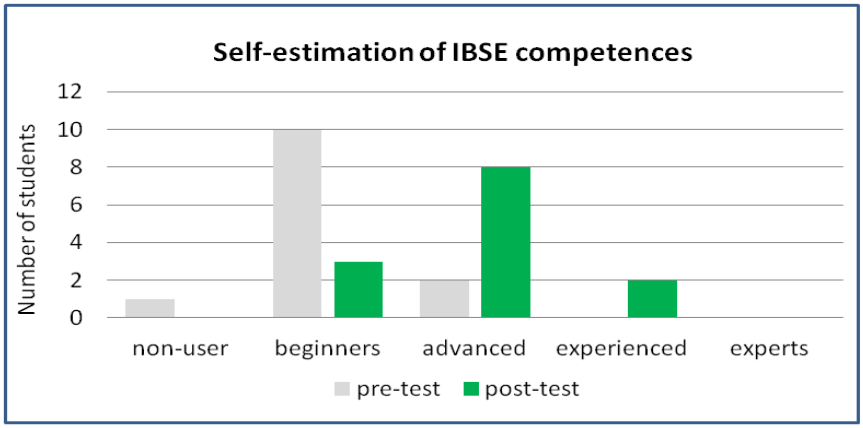

Figure 3. The self- estimation of competences regarding IBSE in the pre-post comparison (N = 15 teacher students; autumn course)

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 approach". 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).

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.

The composition of the IBSE elements "finding a research question", "setting up hypotheses", "collecting data", "analysing data", "interpretation of evidences", "connecting with (former) knowledge", "communicating findings", and "reflection" ranged from 0 (very structured) to 3 (guided) to 6 (very open).

> "*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)

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. 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.

> "*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)

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 surprising. We interpreted that the participants were successfully on their way to become "reflective practitioners".

Community of Learners

Student teachers, teachers and educators successfully set up joint goals (especially in planning the IBSE school projects), focused on IBSE learning using checklists and by planning and testing IBSE activities. Student teachers reflected regularly on their experiences during the INQUIRE meetings by 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. Figure 4 gives an overview about the estimated success of the CoLs.

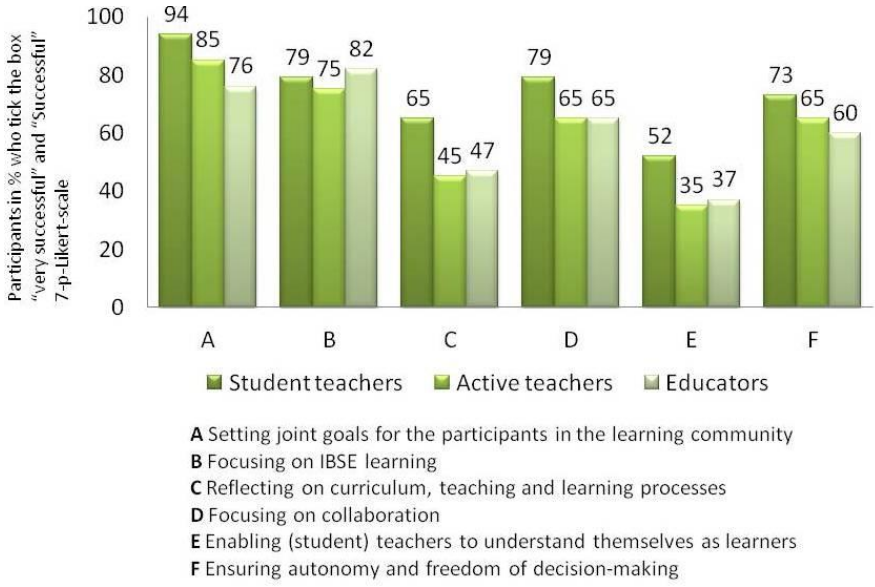

Figure 4. Success of the Community of Learners

Pupils' Learning

In total the school teams developed 12 school projects which differ in content and used methods. Examples are "How to plant a Rhododendron avenue?", "Why do we use bees?", "Climate change and allergies", "Expedition to the Mount Kinabalu", "Rain forests". The teacher students evaluated the pupils' learning with pre-post questionnaires (4-point-Likert scales). The findings show that the school projects and IBSE activities were of interest and relevance for the pupils (95% score with "very interesting"). The subject knowledge increased mainly in the field of facts about biodiversity and the understanding of the interconnection of biodiversity loss and climate change. In nine of the 12 projects we recognized activities to overcome plant blindness.

CONCLUSIONS

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 centres.

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) (resources see http://www.inquirebotany.org)

UniHB is very interested in keeping the contact to the Green Science Centre botanic and the European botanic garden network. In addition, the educators of the Science Centre 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)

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