A NEW MODEL FOR INQUIRY-BASED, ACADEMIC PRE-SERVICE TEACHER EDUCATION

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The paper describes the development and evaluation of a curriculum unit in which 3rd semester pre-service students in pairs developed and tried out a series of IBSE lessons in primary schools. The pre-service students were especially selected for a university-based course whereas until recently all primary teacher education was based in institutions for higher vocational education rather than in universities. With ample guidance from a science educator, scientist, a cooperating teacher and a school-based teacher educator the students were able to develop and teach successful lessons with IBSE features to elementary students who were not used to IBSE. Future development will be focused on achieving the same results with less manpower and on adapting the IBSE course to a regular non-university teacher education setting.

Keywords: IBSE, primary teacher education, pre-service, student teaching, inquiry

University based primary teacher education

In the Netherlands elementary teacher education traditionally has been part of vocational higher education and not of university education. Admission is non-selective; almost anybody with a secondary school diploma, whether vocational or general will be admitted. Recently this has led to many complaints about teachers and teacher education students. There have been two main reactions to these complaints. Firstly national tests have been introduced for language and math in teacher education as a requirement for teacher certification and there is a move towards using these as entrance tests starting 2013. Secondly, several Dutch universities have set up university level elementary teacher education programs jointly with teacher colleges. The purpose is to attract talented students with a strong academic background to the teacher profession. Typically universities recruit students from the selective pre-university stream in secondary school which harbors the upper 20% of the ability spectrum. Some of these students graduated from the pre-university *science* stream and took biology, chemistry, and physics in grades 10 – 12. Others specialised in humanities and languages and did not take science beyond grade 9. In September 2010 the University of Amsterdam and the Hogeschool of Amsterdam started a joint program in which students obtain elementary school teacher certification and a university Bachelor degree in Pedagogy. The program is called UPvA, University Pabo of Amsterdam. Pabo indicates an elementary teacher education program.

The third semester curriculum unit on Inquiry Based Science Education (IBSE)

In the second semester students took a first curriculum unit (2 ECTS) on science and technology education in which they were introduced to alternative conceptions of children and required to design an interview to probe conceptions of children. They also had a weekly day in the primary school assisting the teacher and teaching themselves throughout the school year. During that internship they also taught 2 or 3 science lessons. In the third semester students designed, tested

and evaluated a series of 4 inquiry based science lessons. The goal of this curriculum unit is to develop students' understanding of IBSE, to develop skills in designing IBSE lessons, to practice IBSE teaching skills in a classroom setting, and apply their university research skills to the evaluation of IBSE lessons. The unit is also intended to make the pre-service students more science minded and increase the number of science and technology lessons in the school. Furthermore, through the efforts of the pre-service students, their cooperating teachers get exposed to IBSE lessons as well.

Purpose and research questions

The aim of this study is to describe and evaluate the 2nd year IBSE curriculum unit. First we describe the process of developing and testing science lessons. During this process students received guidance from instructors at the university, scientists and a cooperating teacher in the school.

The second part of this paper consists of an evaluation of the products students produced. In other words, an evaluation of the quality of the science lessons based on criteria for IBSE. Lunetta et al (2007) stated that many activities which are named 'inquiry' do not reach standard criteria of inquiry based learning (Coe, 2012). That is why it is important to investigate the inquiry nature of the lesson materials produced and their implementation in the classroom.

The third purpose of this paper is to evaluate the main elements of the course and generate suggestions for improvement. The elements are the guidance students received, the implementation of the lessons in the schools, and quality of the lessons. An important element of this evaluation is the question whether the goals of this curriculum unit are reached.

Literature

Generally elementary science pre-service students have a very limited background in science (9th grade science or less) and low self-confidence. Usually their science experience has been textbook driven and included limited laboratory experience and rarely IBSE-based investigations (Appleton, 2007). A lack of science content knowledge and a lack of confidence in teaching science could be an explanation for the finding that pre-service teachers do not gain experience with inquiry based learning during their normal teaching practice (Kenny, 2010). In our university based pre-service course students are more confident and have more academic potential even though half of them did not take science beyond 9th grade.

Appleton (2007) emphasizes that elementary science methods courses should in the first place provide a successful experience with interesting science in order to create a positive attitude in prospective teachers. There is no room in the teacher education curriculum to review all major topics of a typical elementary science curriculum, therefore an elementary science course should be example based and integrate science and its pedagogy (Olson & Appleton in Appleton 2007). One way of integrating pedagogy, science and IBSE in an elementary methods course is to have pre-service students construct an IBSE-based lesson series and go through the following stages (Heywood & Parker, 2009):

1. Study the topic of the lesson series, the key concepts, and potential conceptual difficulties including their own misconceptions.
2. Study the corresponding targets in the national curriculum (however, in the Netherlands curriculum targets for science are too vague to be taken seriously).

3. Develop and test a lesson series which integrates science concepts and a pedagogic approach.

When pre-service students develop and test IBSE-based lessons series the guidance from a cooperating teacher is essential. However, most elementary teachers are not able to fulfill this mentoring role (Hudson,2005) due to a weak science background and no IBSE experience. Therefore Kenny (2010) proposes a partnership approach between pre-service teachers and colleague teachers, supported by a university lecturer. Apart from increasing science pedagogical knowledge, this partnership approach also increases the confidence of pre-service teachers to teach science (Kenny, 2010). According to O'Sullivan (2008) pre-service students are more concerned about their subject knowledge than about their pedagogic knowledge at the start of an IBSE course. So we added a scientist to the partnership. The students were introduced to a 7-step instruction model by Van Graft and Kemmers (2007) which is very similar to the commonly known 5E model of Bybee et al. (1997) which –amongst others- is used in the Australian Primary Connections program and contains the following steps: Engage, Explore, Explain, Elaborate, and Evaluate. Pre-service students were encouraged to use the model although with the younger children not all steps of the model were used.

Developing and testing of the IBSE units.

Description of curriculum unit Inquiry Based Learning

The curriculum unit on IBSE was compulsory for second year students of the UPvA. The whole course took five months (September 2011 – January 2012) and a total of 6 ECTS so students were expected to spend about 168 hours. Within this period, students in teams of two developed, tested and evaluated a series of four science lessons about a topic they chose themselves or in some cases the topic was requested by their internship school.

Students worked in couples, because inquiry based learning and teaching is difficult and we wanted real discussion between students on how to put the principles of IBSE into practice. Furthermore students were placed in a group with one or two other couples practicing in the same or nearby schools and two UPvA instructors to discuss the lessons being developed. In this group the eight compulsory guidance sessions took place to prepare the students for the implementation of the IBSE lesson series in their school This manpower investment was unusual, but it was also intended to familiarize non-science UPvA instructors with IBSE. Each session lasted 2 – 4 hours. Also, there was one compulsory meeting with the scientist and one with the cooperating teacher. Students were free to arrange more meetings with the scientist and with the cooperating teacher. The content and number of meetings varied between students, but students had at least one more meeting with the scientist as well as the cooperating teacher. With a few of the 14 lesson series the scientist participated in one of the four lessons and gave a presentation in the lesson. Table 1 shows how the guidance was arranged.

Together with the school students chose an age group for testing their lessons and were linked to a cooperating teacher for that age group. Some lesson series were implemented in the 6-8 age group, others in age 8 – 10 or 10 – 12. The schools and cooperating teachers differed in knowledge, experience and interest in inquiry based learning. Table 2 shows an overview of the topics and the age level at which the lessons were implemented.

Table 1: Overview of the guidance framework and the roles of instructors, scientists, and cooperating teacher.

	Two UPvA instructors		Scientist	Cooperating teacher
	One focusing on teacher skills	One focusing on research skills		
Compulsory meetings	8		1	1
From which organization	'University Pabo of Amsterdam' (UPvA)		University of Amsterdam	Primary school
Main role in guidance	Instruction, IBSE pedagogy Pre-research, Evaluation, Presentation		Content	Teaching skills Adjusting to the class

Table 2 Topics and age level of the science lessons

6-8 years	8-10 years	10-12 years
Experiencing music	Physical effort with sports	Gladiators
	Taste and smell	Burial rituals in different times and cultures
	Sense of smell and taste	Eating and drinking in Roman time
	The deep ocean	Musicality
		Deep in the ocean
		Top sport
		Taste and smell
		Sound of Music

Phases in the process

The curriculum unit in the pre-service lasted one semester, which means a total of five months. This period can be distinguished in three different phases, outlined in Table 3. Phase one lasted six weeks and consisted of instruction and development of the lessons. The students studied the science background of their topic, consulted with the scientist and started developing their lessons in consultation with their UPvA instructors.

The role of the cooperating teacher started with providing information about the children in their class, based on the questions the pre-service students asked during their preparation. In the second phase of the program the role of the cooperating teacher consisted of guiding the students while they tested their lessons in the classroom. During this implementation students gathered information for their evaluation and wrote blogs about their experiences. These blogs were used by the UPvA instructors to follow the process and give feedback. In phase three students evaluated their lessons, based on information gathered during the implementation. Based on this evaluation and their experiences with the implementation, they revised their series of four science lessons. The revised lesson series and the evaluation of the lessons were the final products of the course.

Participants

The participants in this study consisted of 29 2nd year students (six of them were male and 23 were female), ten UPvA instructors, fourteen cooperating teachers, and eight scientists some of whom acted as consultant for several lesson series.

All students had graduated from the pre-university track of secondary school which places them in the top 20% of their age group. Thirteen students had graduated from the science stream in

secondary school, sixteen students from the social sciences stream. The latter group had not taken science since the age of 15 except for a course on public understanding of science. The former group had taken senior secondary physics, biology, and chemistry.

Table 3. Summary of curriculum unit Inquiry Based Learning, 2011-2012

Phase	Main activities
Instruction and development	Study content and pedagogy of inquiry based learning.
September – October 2011	Develop the lessons.
	Consult with scientist.
	Group sessions.
	Plan and prepare for implementation.
Implementation	Test the lessons.
November – December 2011	Write blogs with reflection.
	Collect evaluation data.
Evaluation and revision	Reflect on experience.
December – january 2011/12	Analyze evaluation instruments.
	Present lesson series and evaluation at mini conference
	Revise the lesson series for publication on website.

Timeline

During the implementation of the four science lessons students wrote blogs, which gave inside information about their experiences in developing and teaching the science lessons. Writing the blogs was part of the course requirements. In addition to the blogs, all lessons were observed by the cooperation teacher and a few lessons were observed by the researcher or an UPvA instructor. All other data were gathered after teaching was finished in December. One month after the end of curriculum unit IBSE all participants in this curriculum unit cooperating teachers, scientists and UPvA instructors, were invited by email to fill in a questionnaire. This questionnaire was anonymous and participation was voluntary. The response rate was eight UPvA instructors (80%), seven cooperating teachers (50%), and four scientists (50%).

The data set also includes document analysis to measure the quality of the lessons students produced and self-evaluation by students of the elements of inquiry based learning in their own lessons. All evaluation data that were used during this research are shown in Table 4.

Table 4 Evaluation data

During the course	**After the course**
Students blogs	Questionnaires by students, UPvA instructors, scientists and cooperating teachers
Observations by the cooperating teacher and the researcher	Self-evaluation by students
	Final version of lesson series

Presentation of evaluation data.

Evaluation data included students blogs, questionnaires, observations, self-evaluation and the final version of the lesson series produced by the students.

Student blogs

During the development and implementation of the science lessons students wrote five compulsory blogs. The students' blogs contained information about the process of developing and testing; steps students took in this process, experiences in the class, experiences and role of the scientist, reactions of children during the lessons and an evaluation of the whole process. The selection of the quotes was based on the following questions: 1) Which difficulties did students experience during the developing and testing process?, 2) What kind of classroom experiences did students describe in their blogs?, 3) What did students write about their own learning during the IBSE curriculum unit? The blogs that are quoted below give information that is representative for all student blogs.

Quotes about the implementation and difficulties

It was pleasant that the children right away asked where the pieces came from, a plate? A vase, a beaker? On purpose we did not answer (inquiry learning!). Getting those pieces was really a top idea! Mieke and Mary (pseudonyms), lesson 2, age 10 – 12.

Also we noticed that the children were busy during the experiments. It is of course exciting for them to experiment. Because of that it is helpful to plan a few reflection moments in which children can think about their next step. Ilse and Nico, evaluation blog, age 8-10

Quotes about the learning outcome from students

The lessons series we developed was indeed completely prepared and there was less opportunity to use the input from children in the lessons. We are looking forward to design lesson series in which children design their own experiments. That would mean that we would loose control completely and should not design everything up front. Leo and Cheryl, evaluation blog, age 10-12

It is also important that the teacher reacts neutral. The more the teacher remains outside the thinking process of the children, the nicer and greater the children's designs [of an arena for gladiators] will be. Rita and Jenny, age group 8-10

We learned a lot about the organization of the lessons. We learned that is important to give children enough guidance by the design en implementation of the experiments. It is essential to give children the opportunity to give input, but some guidance and assistance is necessary. Sascha en Myra, evaluation blog, age 10-12

Difficulties students experienced varied from classroom management to organization. There are several students who mention difficulties with the balance between an open and a more prescriptive lesson plan. Students wanted to use the input from the elementary school children during their lessons. However, an open lesson plan is difficult because it is not possible to prepare for all kinds of questions and ideas from the children and the students still lack the experience to predict their questions and reactions. Students are worried about losing control during the lessons.

In their evaluations, students noted that there should be more attention for 1) the determination of the starting level of the children, 2) the input of the children during the lessons, and 3) for seeking the balance between active and reflective moments in the lessons during which children would reflect on their knowledge claims in the light of their experiments. Another point is the planning of activities during the lessons. Some students described a lack of lesson time for the implementation of the hands-on parts of a lesson. Most students right away indicate possible solutions for the difficulties they experienced.

Questionnaires

After completion of the curriculum unit IBSE we invited the UPvA instructors, scientist and cooperating teachers to fill in an evaluation form. Table 5 summarizes results.

Table 5 Results questionnaire administered to the cooperating teacher, scientists, UPvA instructors

Question	Cooperating teacher (n=7)	Scientists (n=4)	UPvA instructor focusing on teacher skills (n=5)	UPvA instructor focusing on research skills (n=3)
I had an opportunity to review het lesson series before it was executed	57 %	75%	80%	100%
And gave feedback	43 %	75%	80%	100%
Focus of the feedback				
Content	57%	100%	80%	67%
Learning goals for elementary school students	72%	25%	80%	67%
IBSE pedagogy	14%	25%	40%	100%
Organization and planning of the lessons	86%	25%	60%	67%
Evaluation-instruments	29%	0%	40%	100%
Teaching skills	57%	0%	60%	33%
(on a 5 point scale, NOT a	**percentage)**			
My knowledge about IBSE is enough to supervise students	2.9	3.8	3.2	4.7

Table 5 shows that the focus of the feedback the students received during the process of developing their lessons varied between the persons who guided the students. All scientists gave feedback on the content of the lessons. The UPvA instructor gave feedback on the IBSE pedagogy and evaluation-instrument. On the other hand only one of the seven cooperating teacher gave feedback on de IBSE pedagogy. The cooperating teachers gave themselves a low score for their own IBSE knowledge.

Evaluation of the lessons series based on the criteria for Inquiry Based Learning

Based on the literature (Bybee et al, 1997; Coe, 2012) we formulated some simple categories to score the lessons. The question was whether the activities listed in column 1 of Table 6 did or did not occur in the lesson series. Students filled in a self-evaluation independently of their partner and the researcher scored the lesson materials on whether or not these children activities were included. Table 6 shows the results separately for lesson series for age 6 – 10 and for age 10 – 12.

In Table 6 there are six criteria on which student scored themselves lower than the researcher. On the other twelve criteria they scored themselves higher than the researcher. An example is criterion 9 '*What did we learn'*, students in the age group 6-10 scored 71% and the age group 10-12 scored 62%, while the researcher scored 25% for both age groups and judged that in most lesson series the final reflection on what did we (the children) learn from our experiments was missing.

According to the students most criteria of IBSE were present in the lessons. Especially *Formulating questions about the topic* and *Observing, measuring* were part of their lessons. Least included were *Interpreting of observations/measurements* and *Reporting orally or in writing* (age group 6-10 years).

The researcher found that *Exploring phenomena in an exploration phase* and *Observing, measuring* were part of most lessons series. According to the researcher the following criteria are least included: *Converting questions to researchable questions*, *Looking back: What did we (the children) learn from our experiments* and *Interpreting of observations/measurements.* Not all these IBSE features can be implemented at every primary age level or in every lesson series; however, *the minds-on collective reflection on what we learned* should be part of teaching at any level.

Table 6 Criteria IBSE

Children activities in the lessons	**Number according to the students 6-10 (N=7)**	**Number according to the researcher 6-10 (N=4)**	**Number according to the students 10 -12 (N=13)**	**Number according to the researcher 10-12 (N=8)**
Exploring phenomena in an exploration phase	71%	100%	70%	75%
Formulating question about the topic	71%	50%	85%	63%
Converting questions into researchable questions	71%	25%	62%	50%
Designing experiments or contributing to the design	71%	50%	54%	50%
Observing, measuring	71%	100%	85%	75%
Interpreting of observations/measurements (thinking back-and-forth between concepts and evidence)	43%	50%	70%	0%
Concluding	57%	75%	100%	63%
Reporting orally or in writing	43%	75%	100%	63%
(looking back) What did we learn	71%	25%	62%	25%

Observations of the lessons series

According to the students 70 percent of cooperating teachers were at least 75 percent of the lessons present in the class during the lessons. That is in line with the results from the cooperating teacher questionnaires. Remarkable is that five students noted in the questionnaire that the cooperating teacher was present in the class only 0 to 25% of the lessons. The cooperating teachers who filled in the questionnaire were at least 50% of time in the class.

Because the cooperating teachers were present in the class during the lessons we can gather information from them about the classroom management of the students. The information about their observations was gathered through questionnaires and interviews. Some examples of comments from cooperating teachers on their evaluation forms were positive: 'The lessons went smoothly, were well prepared and the organization was very good, the children participated well and behaved very well'. Half the comments were positive, half were neutral or negative. An example of a negative quote is: *In the lessons they taught there were organizational matters on which the lesson stranded. Preparation was insufficient*. More information was gathered by observations from the researcher. In most lessons classroom management and organization of the lessons were quite sufficient. An explanation for this can be that students gained experience in teaching IBSE in their second semester and that they prepared their lessons well, based on feedback from the scientist, cooperating teacher and the UPvA instructors.

In one observed lesson a researcher wrote the following in his report:

> This was the fourth and final lesson of the series and children (grade 4, age 9-10) in groups presented their results for the class (Photo 1). Most children of each group had a role in the presentations and they were well prepared. At the end of each presentation the other children in the audience were asked to give a "tip" (suggestion) and a "top". Most common tops were that one of the children presented particularly well. The most common tip was that a particular child should talk louder. Children were not encouraged (nor discouraged) to ask questions about the content of the presentation. Also the pre-service students did not ask content questions. I would have liked to get children to tell what they think they learned about the topic and what they think they learned about investigating. After the presentations one of the pre-service students gave a clear summary about the topic. Throughout the lesson classroom management was very consistent and the class behaved very well, quite surprising to me considering that these were 3rd semester students.

In the observed lesson children gave a presentation about the experiments and their results. All children had a role during the presentations and the presentations were prepared well. The students had an important role in that preparation. However, children and students didn't give any feedback on the content of the presentations. Children did not reflect on their increased content knowledge and research skills. That is something that could be improved in the lessons.

Conclusions

In general we can conclude that the goals of this IBSE unit were reached. Main elements of IBSE were visible, students could develop, teach en evaluate their lessons and the guidance structure worked. We can conclude that these especially selected students with the extensive support structure provided, can develop, teach and evaluate IBSE science lessons. The results of this curriculum unit were well written lesson series ready for use by other teachers.

A very extensive preparation tends to produce rather closed lesson materials with less opportunities to take reactions and suggestions of children into account. That is something students acknowledge, but find difficult to do during the lessons. Overall we can say that pre-service students had very positive experiences with teaching science, which is the first requirement for successful IBSE pre-service preparation (Appleton, 2007).

The guidance structure worked well. The persons who were involved in the process as a supervisor gave the pre-service teachers feedback on different parts of the lessons series. There was also some confusion as the non-science teacher educators themselves had to learn about IBSE as well, which was one of the reasons for the extensive guidance structure. Cooperating teachers gave feedback on the teaching skills and the organization of the lessons. They did not give feedback on the pedagogy of IBSE. The scientist gave feedback on the content of the lesson series and contributed to motivation of the pre-service students. Pre-service students received feedback on the pedagogy of IBSE from de UPvA-instructors in the preparation and evaluation phase. However, students did not receive feedback on their IBSE skills during/after the lessons. We saw that not all elements of IBSE were present in the lessons series. Feedback directly based on the performance in the classroom can help to reach a higher level of IBSE. The improvement of the knowledge and skills about IBSE from cooperating teachers is necessary to improve the implementation of the lessons series.

Another point for improvement is the focus of the feedback from the UPvA-instructors. They should be aware that the criteria *Converting questions to researchable questions*, *Looking back: What did we (the children) learn from our experiments* and *Interpreting of observations/measurements* should be a part of the lessons pre-service teachers develop.

Because of this curriculum unit students learned to design, implement and evaluate science lessons. We expect that this positive experience will have an impact on the number and quality of their future science lessons. Besides that long term effect, there is also a short term impact of this curriculum unit. First of all, cooperating teachers were exposed to IBSE in their own classroom. Second, non-science teacher educators were exposed to IBSE.

Future

The support structure in this curriculum unit was quite extravagant in terms of manpower, 5 small groups of 5 or 6 students each met 8 times with a university and a school—based teacher educator. Such manpower input is not sustainable but was justified in this case as the non-science teachers had to learn about IBSE as well. Furthermore, as mentor teachers get more acquainted and experienced with IBSE through various on-going projects, their role could grow.

Teacher educators in this project are also involved in redesigning the regular non-university teacher education program. Some features of the IBSE curriculum unit will be tried in the regular program but it will be a challenge to provide IBSE training for much larger numbers of pre-service students who have much less academic orientation.

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