Making IBSE Durable through Pre-service Teacher Education

Editor: Ed van den Berg

Knowledge Centre for Teaching and Education

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The EU Fibonacci Project (2010-2013) aims at a large dissemination of inquiry-based science education and inquiry-based mathematics education throughout the European Union. The project partners created and trialed a common approach to Inquiry-Based Science and Mathematics Education in a dissemination process involving 12 Reference Centers and 24 Twin Centers throughout Europe which took account of local contexts. The project has received funding from the European Union's Seventh Framework Programme.

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Cover photo: Exhibition about water organized by pre-service students at the primary school Laterna Magica, STAIJ, IJburg, Amsterdam

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Eefje and Mara with double mirrors

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FOCUS OF THIS BOOKLET

How can we make Inquiry-Based Science and Mathematics Education (IBSME) durable? …. by incorporating it in the pre-service programs for elementary teachers! With pre-service students the training can be much more intensive than with in-service teachers. To have an impact in the classroom the minimum contact time in IBSME in-service and coaching has to be more than 90 hours (Supovitz & Turner, 2000). That number is hard to achieve in in-service but it is quite possible in pre-service teacher education.

From 9 – 11 January 2013 the Hogeschool van Amsterdam (HvA) hosted a field-visit sponsored by the EU Fibonacci project with a focus on pre-service teacher education. HvA developed two programs to strengthen IBSME in pre-service. One is an elective minor (30 ECTS) Science and Technology Education in the regular elementary teacher education program. The other is a pre-service program for academically talented students jointly developed by the University of Amsterdam and the Hogeschool of Amsterdam with inquiry as a major emphasis. The two programs are described in chapters 1 & 3 in this booklet.

If you are still wondering what IBSE is, then read chapter 2 of Ana Blagotinsek of the University of Slovenia. She describes a neat example of an IBSE process with students in elementary teacher education. How do you start with a real world question and initially little knowledge, and how do you investigate the question and eventually generate the knowledge needed to answer it?

During the field-visit each participant presented one particularly successful approach in teacher training, for example, training teachers by 'model teaching' activities with these teachers' own pupils. This method was used in different ways by 4 participants in different countries. They describe this in chapters 4 – 7.

In chapter 8 colleague Frans Van Mulken describes the development of a lesson series on graphs, rate of change, and speed using inquiry strategies inspired by the late mathematician and mathematics educator Hans Freudenthal. He also describes how pre-service students could be trained to teach the lesson series as inquiry.

Simultaneously with this booklet, a Dutch booklet is published with overlapping contents but focused more on the Dutch context.

Questions, suggestions, and comments can be e-mailed to e.van.den.berg@hva.nl

Reference

Supovitz, J.A., Turner, H.M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching*, 37(9), 963-980.

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CHAPTER 1: MINOR SCIENCE AND TECHNOLOGY IN PRE-SERVICE ELEMENTARY EDUCATION

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The impact of in-service training in Science and Technology Education is limited. It is difficult to get quality time from practicing generalist teachers with their busy teaching schedules and hundreds of things to think of. Even an in-service course of 3 or 4 sessions it is still far less than what can be done in a one semester pre-service course. Therefore we decided to introduce the option of a 30 ECTS Minor in the pre-service program. Pre-service students taking this option would be better prepared for teaching IBSE and –after some years of experience- might play a leadership role in S&T education in their respective schools. We made some unusual choices in determining the content of this minor.

The Minor *Science and Technology in Elementary Education* is a 30 ECTS option in the curriculum of pre-service elementary education students at the Hogeschool van Amsterdam. The first offering was Fall 2009 and since then it has been offered every year with an annual enrollment of 12 – 20 students. During this period it was one of only a few Minor programs which attracted a sufficient number of students to be offered each year. This surprised us as pre-service elementary education students are not known for their interest in Science and Technology.

Table 1 Number of participants in minor and as percentage of cohort.

	2009-2010	2010-2011	2011-2012	2012-2013
Number of students enrolled in the minor S&T education (% of total number of students in cohort)	12 (9%)	16 (23%)	18 (23%)	20 (25%)

The minor is offered in the 4th year of a 4-year program for elementary teacher education (starting next year, it will be in the 3rd year). Students have taken compulsory science education units in their 1st and 2nd year and so have encountered the basics about what to teach and how to teach S&T in elementary school and they have been introduced to IBSE (Inquiry Based Science Education).

The program elements and main tasks of the minor are:

1. **Design your own science exhibition.**

Students first visit several science museums/centers for inspirations and orientation and then together plan, develop, and operate a one day science exhibition for an elementary school with a collection of exhibits and interactive experiments which appeals to all age groups (4 – 12 years). Themes have varied, for example “water”, “universe and space exploration”, “robotics” (in combination with lab activities).

Educational outcomes for the pre-service students are: a) a boost for motivation/enthusiasm, b) mastering science concepts and skills for several science experiments and gaining confidence in hands-on science, c) enhanced ability to communicate with children from 4 – 12 about science. Schools are eager to host the exhibition.

Figure 1 Exhibition about water at primary school Laterna Magica, Amsterdam

2. **Literature review and presentation**

Students are required to write a literature review about a science topic (content) and subsequently teach their fellow students about this topic in a short workshop. They are also required to design a lesson activity for a primary grade about this topic. The topics have to be chosen from the Dutch "science canon", a list of 50 important topics in science & technology many of which are not included in school science textbooks.

To provide inspiration for this task there is a small series of seminars on popular science topics with inspiring speakers from the nearby universities. Each seminar concerns one of the topics of the science canon, such as: what is zero (math), big bang (astronomy/physics), or plate tectonics. *Through this activity pre-service students are expected to gain the experience of getting some understanding of a current and popular topic in science -which may or may not be included in typical school textbook science- and gain confidence in dealing with new topics. With a workshop for their fellow students, they also gain experience in teaching their colleagues, which is preparation for their potential role as a S&T coordinator and* *front runner. Designing the lesson activity for children serves as an exercise in translating science knowledge to the primary level.*

3. **Design your own science experiment**

Students conduct a science research project about a self-chosen topic to experience what research in science is. If the students are expected to teach IBSE, they need a workable knowledge of how to set-up experiments and how to proceed from research questions to experiments and to conclusions. Typical Dutch pre-service students do not have this experience, so it is included in the minor. For the kinds of pre-service students we have, practical experience works far better than "learning about research". Through this experience students learn to formulate research questions and design experiments. They get experience with data handling, reaching conclusions, and considering the *weak and strong points of their experiments.* Examples of original research have included:

One student had a grandmother who was convinced that putting flowers in a vase with Sprite or 7-Up would make the flowers live longer. The student was skeptical and did a project where she took red roses and put them in different solutions such as tap water, bubble water (water with CO_2), cola, water with sugar, water with 'flower food' (the little bags you get from the florist with your flowers) and Sprite to see in which solution flowers looked best and stayed fresh longest. The water with 'flower food' appeared to be the best, but surprisingly Sprite was a close second. All the other fluids did worse, especially the water with sugar.

Figure 2 Flowers in water with different additions

Another student was wondering which toilet stall in a public toilet would be the cleanest, the ones nearest to the door, or the ones that were farthest away? She reasoned that most people would pick the closest, so she herself always took the last stall, but maybe other people were reasoning the same way and the stall at the end would be used the most (and thus be dirtiest). Or do people prefer the middle ground and take a stall in the middle? She used petri dishes to grow bacteria cultures from several public toilets and also observed for a while how many people used the stalls (she reasoned it would be possible a stall would get dirty from only one person, thus ruining her results). She concluded from the observations that the stall farthest away was used the least. The bacteria cultures followed this pattern: the last stall tended to be the cleanest, but not in all cases.

4. **Develop your own inquiry-based lesson series**

Students first teach an IBSE lesson series of 4 or 5 lessons in their internship school using existing materials. So they experience first-hand what IBSE materials should look like and how to use them in the classroom. Then they have to develop, teach, and evaluate their own lesson series. In each case there should be 4 or 5 lessons (they usually work in couples, but this is voluntary). This is because so much of S&T teaching in the Netherlands consists of one-time activities. We want to stress learning progressions and development of concepts over time. The lesson series should consist of a teacher guide with lesson plans, activity sheets for pupils, a list of necessary materials, and an evaluation report. They also do a small pre-study to ascertain the starting situation of the pupils, by testing the pupils on pre- or misconceptions. *By going through the experience of teaching an IBSE lesson series twice, pre-service students get experience with the key requirements/ingredients of IBSE teaching and learn how to convert a topic into an IBSE approach. Doing this together with a fellow pre-service student greatly helps to cross the various thresholds, compensate for each other's still limited classroom teaching skills, and it deepens the level of reflection.* Some examples of lesson series produced are:

Figure 3 Village made by grade 3 pupils

- A lessons series on bonds in brickwork (for grades 3&4 designed by Anat Ginton): pupils first observed brickwork in the vicinity of their school, then worked with Lego and sugar cubes to ascertain what were the strongest patterns in brick laying. Based on that experience the pupils designed a house, which they build from little bricks. Additional challenges were that there should be windows and doors in the houses, and of course roofs. The houses from the entire class made up a village, which was presented to parents and other pupils (figure 3).

- A lesson series on optical illusions (for grades 5&6): First, several kinds of optical illusions were investigated (how do they 'work'?). Then pupils were asked to make their own optical illusion. A few 'doable' illusions were selected for this task beforehand. For example the kind where you see two pictures in one, depending on how you look at the image.

- A lesson series on smell (for Kindergarten): During several lessons children were exposed to strong smells. Then mixtures of two smells were offered. The pupils were then asked to design a perfume: which two smells do you think smell well together? The pupils investigated several options. They also designed a bottle and label for their own perfume.

5. **Movie project (recently added in the 2012/13 course)**

Students make small instruction films about IBSE for pupils in elementary school, including lesson materials, which are placed on a blog website. The movies are shown in several class rooms in Amsterdam and the activities are carried out by the pupils. The students are available for questions by chat and Skype. The results of the experiments are then placed back on the blog, so results between schools and classes can be compared (an interesting feature when doing IBSE: not all experiments end the same). This project allows the students to offer science lessons to a much wider audience: any class which wants to participate can do so and gets support from the students. The students also have to think very carefully about what they can accomplish in this lesson and what needs to be included in movie and lesson materials. They are dependent on what the pupils and the cooperating teacher can do on their own (without any preparation or prior knowledge). This turns out to be quite challenging.

6. Weekly class sessions

There are weekly class sessions about different aspects of S&T teaching. Topics include exhibitions, various aspects of IBSE and designing IBSE lessons, how to integrate language and mathematics skills in science lessons, but also specialized topics such as a session on using sensors and a session about robotics.

Students are evaluated with a science concept test and a portfolio based on task 1 – 6.

With the recent attention for S&T education schools have been appointing S&T coordinators who guide the development in their school of an S&T curriculum for age 4 – 12 and who assist their teacher colleagues in choosing and preparing science activities for their pupils. A coordinator might get a few hours a week free of teaching in order to carry out coordination tasks. We hope that our alumni with an S&T minor, after getting some years of basic teacher experience, will qualify for such leadership posts in S&T education. With several alumni this is already the case.

The strengths of our minor program are a) it succeeds in attracting students, b) there is a varied program which students are quite positive about, c) some alumni already play a major role in their school but we do not know how many and it is too early yet to tell. Challenges to the program are d) the rather heterogeneous input, some students have almost no secondary science background, others may have taken up science up to grade 12; e) this year the whole pre-service curriculum is being changed which will have major implications for the Minor; f) quality guidance of student lesson development (task 4) takes more time than S&T lecturers have.

Problems, dilemma's

As the current intake of students in the pre-service program in past years has been very heterogeneous, the background science knowledge of students in the minor varies greatly. In the minor we opted to not reteach basic concepts of secondary school science but focus on key concepts of the canon and on concepts-as-needed for the lesson series.

It is difficult to arrange for sufficient lecturer time for proper feedback on the lesson series and other tasks but so far it is working out. Assistance from mentors in the internship schools of the students is very limited as most do not trust themselves well with regard to S&T. In placement in internships these students S&T interest was not taken into account. However, as our network of schools with more S&T and IBSE activities is expanding, we expect to be able to place the students in environments where they can get more support and also contribute more to further school development in S&T.

Until now the influx of students in this minor program has been sufficient to keep the program going, but if the number of students drops the program will not be offered because of funding issues. This is a serious concern, because the total number of students in the pre-service training is expected to drop due to tighter selection at entrance and during the first two years of the program. There will also be more competition for the students that will be there because the number of Minors offered is expected to increase in coming years.

CHAPTER 2: THE CHOCOLATE PROBLEM – AN EXAMPLE OF IBSE

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In inquiry based science education (IBSE) pupils are actively involved in the learning process right from the start – choosing the topics and planning the experiments, and active in all later stages. This approach allows them ownership of the learning process and contributes to motivation for learning. As such, it should also be included in pre-service teachers' education. This practical example describes introducing inquiry to future lower secondary physics teachers, studying in 3rd year at The Faculty of Education in Ljubljana, Slovenia.

Formulating a question

As motivation is an important factor, the teacher should provide **a motivating starting point** for inquiry. The initial setting is planning an excursion, particularly, which snack pupils should take with them. As chocolate is always on the list in at least one form (bars, biscuits, …), and is known to melt quickly and cause a mess, the first form of the problem to investigate is "Which chocolate is best for a snack?". It is an interesting question, but in this form it is not yet appropriate for IBSE. But it can become, with help from the teacher.

Pupils are inquisitive and provide a lot of questions, to which they would like to find an answer by themselves. But only narrow spectra of questions can be answered by an inquiry, conducted in the classroom. The teacher has to comment on how to reach the answer to all questions **and help students to reformulate questions** in a form, which can be answered by inquiry.

In "the chocolate problem" and in general, the teacher has to guide pupils in refining and narrowing the question and in our case, help them decide what the meaning of "the best" chocolate is. Is this the tastiest one? As this depends on personal preferences, everyone has a different and personal, answer, which cannot be objectively disputed. Or is it the chocolate which does not melt so quickly? In this case, time, required for melting can be measured and objectively compared. Or is the best the chocolate, which melts at the highest temperature? Measuring temperature is also possible in classroom circumstances.

Only the first step in the inquiry has been done so far. From the initial interest of the pupils we have developed questions, possible to investigate. And this is an important role of the teacher, conducting IBSE.

Our students decided that high temperatures in buses are problematic for chocolate snacks, so they chose the question "Which chocolate melts at the highest temperature?" and set a hypothesis that darker chocolates melt at higher temperatures: “The higher the cocoa percentage, the higher the melting point.” Reason for this was experience with butter and milk fat, ingredients of milk chocolates, which are both melting at room temperatures.

Hypothesis and planning

Stating their justified expectations about the outcome of the inquiry is an important phase in the IBSE process. **Stating a hypothesis** requires **recalling previous knowledge and experience**, related to the new problem.

These are helpful also in the next phase**, planning the investigation**, where **choosing variables and constants** (or controlled variables) is necessary, to ensure **fair testing**. Our students decided that the percentage of the cocoa in the chocolate should be the independent variable (intentionally varied to study the impact of it on the outcome), melting temperature the dependent variable (measureable quantity, affected by the independent variable) and size of the sample and method of heating to be controlled (kept constant), to provide a fair test. The teacher’s role in the planning phase is to guide pupils by **asking questions**, helping pupils to **reflect upon the fairness of their testing and whether their plan is corresponding** to the research question. When challenged how they will objectively decide when the chocolate is melted, our students decided it will not be a problem, “as chocolate bars are known to change shape when warmed”.

Students planned to put rectangular pieces of the chocolate on the plate, and let the plate float in a hot water bath. The temperature of the water would be gradually increased (and measured), and shape of pieces of chocolate observed. When the piece would change its shape (to a pool), they would measure the temperature of water bath and declare it the melting point of the sample.

Experimenting

When put in action, the plan turned out to have a fault. The chocolate pieces did not change shape, although a pool of melted chocolate was visible in the middle of each rectangle. So they **modified their plan** and scraped chocolate in small irregular grains, spread them in a thin layer over the aluminium foil, put it over the pot with heated water and measured the temperature of the air below it. Small grains did visibly change shape at a certain temperature, but results were surprising. It turned out those chocolates with low percentage of cocoa melted at higher temperatures. Samples with higher proportions of cocoa had approximately the same melting temperature around 33°C.

Difficulties are bound to arise during the process of inquiry and the teacher’s role is to **help modify the plan and keep focus**. And, if possible, show the pupils, that it is possible to **learn also from mistakes**.

Reporting, reflecting, looking for further information

Language skills, ability to exchange science knowledge, to reason and to reflect are developed with IBSE, if the teacher provides time and space for it. **Reporting** was incorporated also in our learning sequence. Students prepared posters and oral presentations on their inquiries. They were also intrigued by the results and carried out a small additional research on the internet and found out, that melting temperature of pure cocoa is 33°C. This explained why all samples with high cocoa percentage had the same melting temperature and they concluded that cocoa properties prevail over other ingredients' at a certain proportion in the sample.

Conclusion

The IBSE learning sequence was conducted in two two-hour sessions (4x 45 minutes), starting with a brief explanation of what IBSE is (with special attention to teacher's role) and presenting possible inquiries. Students chose their favourite topics and formed their inquiry question. They also designed the plan and formulated a list of necessary equipment. This was done during the first meeting and enabled us to prepare required accessories for the second meeting in the following week.

In the second meeting they conducted the experiments and prepared posters. Reporting was done separately in front of a broader audience to provide exchange between different study majors. Posters were put on display in the department to enable discussions, questions and also to enable affirmation of the students involved.

Follow-up

One could imagine a follow-up about the question how chocolate bars could be packaged for a hot day out on the bus. How to prevent melting?

CHAPTER 3: MAKING IBSE DURABLE IN A UNIVERSITY-BASED PRE-SERVICE PROGRAM WITH SELECTED STUDENTS

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The paper describes the IBSE (Inquiry-Based Science Education) component of a newly developed university based pre-service elementary teacher education program jointly operated by the University of Amsterdam and the Hogeschool of Amsterdam. The pre-service students are especially selected for a university-based program whereas until recently all primary teacher education was based in institutions for higher vocational and professional education rather than in universities. With ample guidance from a science educator, scientist, a cooperating teacher and a school-based teacher educator the students are able to develop and teach successful lessons with IBSE features to elementary students who were not used to IBSE. This is an opportunity to get talented pre-service students involved in IBSE.

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 still 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. 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 (in our program about 40%) graduated from the pre-university *science* stream and took biology, chemistry, and physics in grades 10 – 12. Others (about 60%) 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. In four years students obtain a double degree: a BA in Pedagogy awarded by the university and a

BA in Elementary Education awarded by the Hogeschool of Amsterdam. The two programs are fully integrated with a strong school practice component.

As we have argued in the introduction, IBSE training in a pre-service program can be much more intensive than in in-service. This university-based program for a selective group of students has the potential to create a group of future leaders in IBSE and S&T education in the schools.

S&T/IBSE Education

The compulsory S&T IBSE education components are concentrated in semesters 2 and 3. Later in the third and fourth year students conduct research projects where an S&T/IBSE focus is one of the options. The compulsory S&T components are part of a series of program activities which are linked directly with the internships in elementary schools. In the first and second year of the program students spend 1 day per week in elementary schools where they assist teachers, teach lessons themselves and carry out tasks for their teacher education program. In the following we will describe the three tasks to be completed with respect to S&T/IBSE preparation.

Task 1: Children conceptions and developing a lesson series (2+1 ECTS).

Students in duo's interview 8 children in their internship school about a science phenomenon such as the water cycle: *where does the rain come from, where does it go to?* The interviews are with children ages 4 – 12 so the students will encounter a variety of views including unexpected alternative conceptions. They then choose a particular grade level and design a series of 3 lessons about the main concepts related to the science phenomenon. The lessons are implemented in the classroom and data for evaluation are collected including video. Finally the students present the results to each other. Throughout the process formative evaluation is emphasized and some student duo's are able to monitor the development of children's ideas to some extent even though this is the first science lesson series they teach.

The intended educational outcomes of this activity are: pre-service students discover that children of all ages already have their own "alternative" ideas about science phenomena and that these ideas are very interesting but can be quite wrong and that these ideas need to be taken into account when teaching and their development needs to be monitored through embedded formative assessment. Pre-service students encounter the basic requirements of IBSE and get a first experience in implementing it in the classroom and evaluating the experience.

Figures 1 & 2: First year pre-service students present their work to each other in the presence of international visitors Dr. Yves Beernaert and Dr. David Jasmin.

Student output: video material on interview and classroom lessons, oral presentation in class, written report.

Preparation for the activity is done through a starting lecture and further work is done in tutorial groups. In total there are five tutorial meetings in which students receive feedback from the science educator and a school-based teacher educator. Apart from the guidance during the tutorial meetings students attend a course about science and technology education. This course consists of four lectures and seven smaller group sessions (1 EC).

Task 2: Organizing a Science and Technology exhibition

At the start of the third semester students are told that in 10 days they should have prepared a science and technology exhibition in an elementary school. So they have to get ready in a very short time and that generates a lot of tension but also much creativity. The exhibition should be interesting for a selected age group (this year grades 4 and 5) and there should be interactive exhibits. The students decide on a theme. For example, last years' exhibit was on space and space exploration with models and exhibits on the planets, the seasons, telescopes, space suits, and water rocket demo's outside the school. The year before the exhibition was about construction of a new metro line in Amsterdam.

During the preparation time students had to answer a central question: question 'What are characteristics of a good exhibit?' They had to answer this question based on a visit to a Science Center, readings about requirements for a good exhibition and group discussion.

Educational outcomes for the pre-service students are: a) a boost for motivation/enthusiasm, b) mastering science concepts and skills for several science experiments and gaining confidence in hands-on science, c) enhanced ability to communicate with children from 4 – 12 about science, and d) collaborating as a group to create an event in the school. Schools are eager to host the exhibition.

Student output: Exhibition and photo documentation

Figure 3 Exhibition on construction of North-South metroline in Amsterdam. Photo: Sido Notermans.

Figure 4 What happens to houses when there is drilling underneath? Photo: Sido Notermans.

Intermezzo on pre-service methods courses

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, 2010):

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 (see Task 3). 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/motivate, Explore phenomena, Explain phenomena, Elaborate (investigations designed by pupils and based on their questions), and Evaluate. Pre-service students were strongly encouraged to use the model although with the younger children not all steps of the model were used.

Task 3: Developing, trying out, evaluating, and presenting an IBSE lesson series (6 ECTS).

Over a 5-month period from September – January students develop, try out, and evaluate a 4-lesson IBSE series. The activity is worth 6 ECTS so students are expected to spend about 168 hours. The topic can be a request from the internship school (preferred) or can be chosen from a list the teacher education program presents. This list is based on the scientists who participate in this project and their areas of expertise. Students work in couples, because inquiry based learning and teaching is difficult and we want real discussion between students on how to put the principles of IBSE into practice. Furthermore students are placed in a tutorial group with some other couples practicing in the same or nearby schools and an instructor to discuss the lessons being developed. In this group eight tutorial sessions take place to prepare the students for the implementation of the IBSE lesson series in their school. Each session lasts 2 – 4 hours. Also, there is one compulsory meeting with a scientist and one with the cooperating teacher. The scientist acts as resource person for the unit and students learn this way how to approach experts and make use of them. The scientists are usually enthusiastic and very willing to share their passion. Students are free to arrange more meetings with the scientist and with the cooperating teacher and most have at least one more meeting with either. Sometimes a scientist volunteers to take a role in the lesson series and gives a presentation during one of the lessons. Table 1 shows how the guidance is arranged.

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 Preparation, Evaluation, Presentation		Content	Teaching skills Adjusting to the class

Together with the school students choose an age group for testing their lessons and are linked to a cooperating teacher for that age group. The schools and cooperating teachers very much differ in knowledge, experience and interest with regard to inquiry based learning.

Topics of lesson series vary widely, for example: Taste and Smell (age 4-6; another version age 8-10), Solidifying/Melting (age 4–6), Experiencing Music (age 6–8), Comparing Houses Now and in the Past (age 6–8), Gladiators (10-12), Life Deep in the Ocean (10-12), Sound of Music (10-12).

Phases in the process

Students have 6 ECTS (168 hours) in 1 semester to execute task 3 spread over five months. There are three phases as outlined in Table 2. A preparation phase takes six weeks. The students study the science background of their topic, consult with the scientist and start developing their lessons in consultation with their UPvA instructors. Then follows the implementation phase during which the students teach 4 IBSE lessons, record their experiences in blogs, and collect evaluation data. Through the blogs UPvA instructors follow the process and give feedback. During the evaluation phase students analyze their experience and evaluation data and revise the teacher guide and worksheets of their lesson series. The revised lesson series and the evaluation of the lessons are the final products of the course which students present in a final session. The lesson series then go through an editorial committee and –if approved- are published on a website for teachers.

The cooperating teacher (mentor) may or may not involve herself in the choice of topic. The mentor may be different from the mentor in the student's internship as the lesson series might aim at a different age level. She does give prior information about the children and answers questions from students about children and classroom/school procedures. In the teaching phase of the program the mentor guides the students while they test their lessons in the classroom. The involvement of the mentor varies greatly from passive observer to active advisor.

Table 2. Overview Task 3 development of IBSE lesson series

Phase	Main activities
Instruction and development	Study content and pedagogy of inquiry based learning
September – October	Consult with scientist
	Develop the lessons
	Tutorial group sessions.
	Plan and prepare for implementation
Implementation	Teach the lessons in the classroom
November – December	Write blogs with reflection
	Collect evaluation data and video from the classroom
Evaluation and revision	Reflect on experience
December – January	Analyze evaluation instruments.
	Present lesson series and evaluation at mini conference
	Revise the lesson series for publication on website

Student output: blogs on lesson experiences, video materials recordings of the lessons, evaluation data collected, final version of teacher guide of 4 lessons, presentation about the lessons and evaluation. In 2011/12 29 students produced 14 lesson series. In 2012/13 39 students produced 19 lesson series.

An extensive evaluation was conducted in 2012 and presented at the Fibonacci conference in Leicester and published on the conference website (Herik et al, 2012). In the following we present some main points.

In most lessons classroom management and organization of the lessons were sufficient as most children were on task. Students had already been 1 day/week in the classroom for more than 2 semesters. Furthermore they gained experience in teaching IBSE in their second semester and they prepared their lessons well, based on feedback from the scientist, cooperating teacher and the UPvA instructors. In some lessons classroom management was still a problem and in most lessons it could still be better, for example, in a lesson about influence of physical effort on heart, breathing, and sweating some children were running up and down stairs to break their time record, but then suddenly switched back to measure heart beats. Furthermore, these 4th graders had trouble seeing the connections between their research questions, their measurements, and conclusions.

Most lesson series included the main phases of IBSE such as exploring phenomena, asking questions, designing experiments, observing/measuring, concluding and presenting. However, in about half the lesson series experiments were already pre-planned and provided by the pre-service students. It is very well possible to involve the children in conceiving experiments. For example, grade 4 children thought of all kinds of questions about exercise, heartbeat, breathing, and sweating and they proposed experiments. The pre-service students then tried out the experiments ahead of time, improved them to get more valid and reliable measurements, and next lesson let the children work with the modified versions.

	
Figure 5: Grade 4 presents about tastes and smells.	Figure 6: Feeling your heart beat after running up and down the stairs and measuring how long it takes to blow up a plastic bag when you are out of breath.

Yet the degree of openness remains a difficult issue. A very extensive preparation tends to produce rather closed lesson materials with fewer opportunities to take reactions and suggestions of children into account. That is something students acknowledge, but they find it difficult to do during the lessons as can be seen in blog comments:

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 lose control completely and should not design everything up front. Leo and Cheryl blog lesson series for age 10-12

We learned a lot about the organization of the lessons. We learned that it 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, blog lesson series for age 10-12

There are also problems with the interpretation and conclusion phase of IBSE as students themselves noticed:

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 blog, lesson series for age 8-10

An observer wrote:

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 (Figure 5). 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 thought they learned about the topic of Taste and Smell and what they thought 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.(E. van den Berg, 8 December 2011).

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. 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.

Insufficient attention to interpretation and reflection is not just a problem in lessons of pre-service students, but a major problem in any hands-on teaching also at the secondary level where teaching is done by science specialists (Abraham & Millar, 2008). Richard Gunstone once formulated it as follows: *Are pupils only manipulating equipment (hands-on) or are they also manipulating ideas (minds-on)?*

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 indicated possible solutions for the difficulties they experienced.

Output: So far 25 lesson series –teacher guides, pupil worksheets, background information- have been uploaded to a website for elementary teachers (http://www.wka.uva.nl/lesmateriaal-po). Of these 25, seven have become public and another 5 have been approved by the editors provided some small changes are made. Please note that these are lesson **series,** children deal with the same topic for at least 4 lessons. In the Netherlands most S&T activities in the classroom are one time activities in one lesson thus unlikely to result in lasting learning. So lesson series should be very welcome.

The pre-service students are required to document their lesson series well, to provide arguments for their educational choices, etc. Some are doing that surprisingly well for 3rd semester students. However this results in documents of 20 – 30 pages while practicing teachers will not read more than a few pages. So there is a tension between a good training for IBSE lesson development and the very limited documentation teachers want. The editors have now proposed solutions for this such as making a very short teacher guide and pupil worksheets and moving most information to a solid background document. Another problem in the lesson series is that true IBSE should offer opportunities to the children to formulate and investigate their own questions while pre-service students like to anticipate and plan everything as they do not have sufficient experience yet to improvise. That is a more difficult problem to solve but some student couples were able to do this very well.

Summary, problems, dilemma's

In short, with these selected students it is possible to develop and implement a successful IBSE lesson series with children who have not previously been exposed to hands-on/minds-on science. Main elements of IBSE were visible in the lessons, students could develop, teach en evaluate their lessons and the guidance structure worked well. Just like experienced S&T teachers, the students still experienced problems in involving children in the formulation of research questions and experimental set-ups and in getting the children to reflect meaningfully on the outcomes of the experiments. Overall we can say that pre-service students had positive experiences with teaching science, which is the first requirement for successful IBSE pre-service preparation (Appleton, 2007).

The guidance structure is quite extensive and could be reduced if the mentor teacher would be more familiar with S&T and IBSE. That is not yet the case, but through selection and training of mentors the situation could be improved. Students did not yet receive sufficient feedback from their mentor on their implementation of IBSE in the classroom, but working in duo's helped, students do analyze the lessons critically together as their blogs and interviews show. Working in duo's is crucial. Also the UPvA instructors still need to learn more about practical ways to implement primary S&T/IBSE education.

After Tasks 1 – 3 some students are a bit saturated with IBSE. They feel sufficiently confident to apply IBSE, but they also wonder whether this elaborate teaching method should be applied throughout. For teaching important research and design skills, IBSE is necessary. For teaching concepts IBSE is one of many methods which could be used although it is always necessary to have some hands-on/minds-on component to visualize concepts and stimulate the back-and-forth thinking between concepts and phenomena. In science teaching methods courses IBSE should not be presented as the only method.

In the future these selected students could play an important role in developing S&T education in primary schools if they are placed as teachers in schools which want to develop their S&T program and get the opportunity to use their knowledge and skill in applying IBSE. We will try to play a role in matching graduating students with S&T network schools.

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CHAPTER 4: TEACHER EDUCATORS TEACHING PRE-SERVICE STUDENTS IN A SCHOOL SETTING: DEVELOPING A PEDAGOGY FOR HYBRID SPACES

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At Liverpool Hope University the mathematics education team has been developing hybrid spaces, defined by Zeichner (2010) as spaces which "*bring together school and university based teacher educators and practitioners and academic knowledge in new ways to enhance the learning of prospective teachers"* (p92). These spaces require a new pedagogy to support more democratic ways of working between university tutors, experienced teachers and pre-service, beginning teachers.

The one year Postgraduate Certificate of Education (PGCE) Secondary Course in mathematics has for the last three years included a project known as the Saturated Learning Project (SLP). This project has transferred the site of learning for the university sessions into a partner school. The sessions have involved joint planning between the school and university tutor and are centred on practical teaching sessions. These sessions are delivered by the whole cohort of around thirty pre-service mathematics teachers working with groups of pupils, in a common space, usually the school hall. The aim of the project has been twofold; firstly to form a bridge between the university and school experiences and secondly to address some of the limitations of the traditional solo placement where the pre-service teacher is situated alone in a school with a supporting mentor.

Allen (2009) notes "prospective teachers during pre-service training value both the theory they learn in campus and the practice that they observe in schools. However once they become practitioners they privilege the latter." (p647). One of the issues for the university tutor is to continue to have influence on emerging practice whilst the beginning teacher is situated in school. By moving the site of the university sessions into the school classroom the connections between academic and professional learning can be reinforced. The project involved applying theories of practical and inquiry based approaches to teaching and learning mathematics in the shared context of a classroom. Each week, for ten weeks, the same pre-service teachers work with the same group of pupils forming small communities of practice (Lave &Wenger 1991).

Before and after the teaching sessions one hour workshops are led by the university tutor which allows time for anticipatory reflection (van Manen, 1995) of what may be the common errors, misconceptions and difficulties in teaching the topic and post reflections on the outcomes from the sessions. The Saturated Learning Project experience provides the opportunity to develop practices which are not the same as those developed in the students' individual placement schools and affords knowledge of a different practical and pedagogical nature to reflect on and against. Wilson (2005) notes that one of the dangers of the university–school model, is that pre service teachers spend 2/3 of their time in school where there is often limited opportunity to discuss with anyone the emerging practice on a practical level. She argues that this "may severely limit the novice teachers' capacity to be critically reflective of their own practice" (p375). The Saturated Learning Project creates a reflective space which allows time for consideration of some of these important practical issues with peers, teachers and university tutor. The pre and post reflective sessions are a collective experience, as Buysee et al (2003) note knowledge is best "*understood through critical reflection with others who share the same experience"(p268).* The time to reflect together is an important element of the underpinning pedagogy for the project. All of the pre- service teachers have the commonality of teaching the same topic whilst at the same time all have a different experience according to the responses and engagement of the particular pupils they work with. These two elements of commonality and difference afford rich collaborative discussions and reflections amongst the pre-service teachers, and between the beginning teachers, experienced teachers and university tutor.

Benefits for the school are also important, the impact of the project on pupil learning has been evaluated positively by the teachers and pupils involved. Initial concerns about the reaction of the pupils to working in either a one-to-one, or a two-to-one situation with a beginning teacher have been unfounded. The evaluations have been overwhelmingly positive with the pupils responding to individual attention from the pre service teachers. School teachers who have been involved have noted increased levels of engagement by the pupils. They have also welcomed the opportunity to observe their pupils and how they interact with the mathematics and with the pre service teachers working with them.

Figure 1: Pairs of PGCE Secondary pre service teachers working with groups of 3-4 Y11 pupils (15-16 years). The pupils are investigating geometric properties of regular polygons and using origami to investigate angle properties of triangles and quadrilaterals.

Figure 2: PGCE Primary pre-service teachers working with individual Year 6 examination pupils (10-11years). The pre service teachers are learning about common misconceptions held by pupils. Their assessments of areas of weakness are feed back to the class teacher to inform subsequent planning.

The success of the project in secondary ITE (Initial Teacher Education) is now being replicated in primary ITE. The PGCE primary specialist mathematics cohort of 12 pre service teachers has been working in a similarly collaborative mode with a partner primary school. Over a series of weeks they have supported a group of final year, Y6, pupils (10-11 years old) with examination preparation and in addition worked with the school's mathematics coordinator to prepare activities for all years across the school as part of a "Maths Week". The pre-service teachers gained valuable insights into the preconceptions and misconceptions of learners whilst providing valuable support for the pupils before their examinations. This contrasted with the experience of the creation and delivery of enriching activities for pupils across the primary age range (5-11 years). Again the spaces created before and after teaching to discuss and reflect in collaboration with peers and with the class teacher and tutor have been a key element of the project.

The creation of such hybrid spaces where the university tutor and school teacher work more closely together with pre-service teachers and pupils has resulted in more expansive learning environments (Fuller and Unwin, 2003) for the pre service teachers. The opportunities for collaborative learning in an environment of mutual support and co-inquiry are increased and the boundaries between aspects of professional, practical knowledge and academic, theoretical knowledge are increasingly contested. These areas of contestation extend the potential for learning, strengthening the linkages between the pre-service teachers practical participation of everyday practice in the classroom with underpinning theoretical perspectives.

Context: Teacher Education Changes in England

Initial Teacher Education (ITE) in England is at present more than at any other time in its history a site of great contestation and change. The pace of political reform is exponential and will force unparalleled and abrupt cultural and organizational changes by universities and partner schools. The new coalition government's drive to shift the focus of control of teacher education into schools by reforming the current system has significant and not yet fully understood implications for Higher Education. Placing greater emphasis on the workplace and employment based routes will require university Initial Teacher Educators to reconsider and reposition themselves within the field. Justifying critically the unique and valuable learning spaces created for the beginning teacher by the university is an important step forward towards a new vision of professional learning. Changes within the university coincided forcing a re-visioning of the way we work with schools moving to a more collaborative rather than cooperative model of partnership and viewing Professional Learning as a process of transformation rather than replication.

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CHAPTER 5: IBSE IN-SERVICE TRAINING WITH TEACHERS AND THEIR PUPILS IN ROMANIA

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The Center for Science Education and Training, at the National Institute for Laser, Plasma and Radiation Physics, coordinator of the Fibonacci project in Romania offers two courses on Inquiry-Based Science Education (IBSE) for primary and middle school science teachers. The courses are the first ones accredited by the Romanian Ministry of Education. Our experience in providing these courses to more than 800 primary teachers indicated several critical drawbacks of the Romanian educational system in applying IBSE:

- teachers are not at all trained in using this method;
- they miss the adequate means to use this approach and there is a lack of time in running such classes;
- formative assessment of students is hardly used in Romanian schools;
- science education targets mostly the transfer of knowledge and less the development of competences;
- pupils are taught and learn mainly on individual basis and rarely cooperate on class assignments.

The new Law of National Education promulgated in 2011 tries to overcome some of these difficulties by requiring the development of core competences, some of them overlapping with IBSE inquiry skills.

In order to assist Romanian primary teachers in acquiring the competences promoted by IBSE we designed a model 1-session course for interested teachers' communities. Within this new approach **we are teaching simultaneously both primary school pupils and teachers.** Within the session we run a lesson for pupils according to IBSE principles (questioning, dialog, development of hypotheses, designing of a fair test, the use of pupil notebooks, preparation of conclusions, communication and debating the results, collaboration and team work, buildup of new knowledge based on pupils previous experience) and a group of teachers attends the lesson and observes our approach with their pupils. In the meantime, we acquaint primary school teachers with formative assessment. For this purpose, teachers receive evaluation sheets and are asked to assess the participating pupils as the class is run. The evaluation questionnaire refers to skills and competences presumed to be acquired by pupils during the lesson (content knowledge, competences and skills, attitudes).

At the beginning of each demo session we spend 30 to 40 minutes with the teachers

involved in this training, explaining to them their role and tasks. At the end of the session a feedback discussion with the teachers offers us the opportunity to evaluate in real time the activity through teachers' eyes. Typically 10 – 12 teachers each bring 2 or 3 pupils for a 4-hour session. This approach proved to be very popular among the primary school teachers and students as they form an integrated learning community, by involving actively all participants in a collaborative manner.

CHAPTER 6: IBSE IN-SERVICE TRAINING WITH TEACHERS AND THEIR PUPILS IN AN AUSTRIAN 'LERNGARTEN'

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NAWImix is the third location of the Pedagogic Center of Natural Sciences, Viktor Frankl University. The major part of advanced teacher training with respect to Natural Sciences takes part here. The actual offerings focus on inquiry activities for visiting first to twelfth grade classes and will be further expanded to include Kindergarten as well. The offerings cover Physics, Chemistry and Biology. Expansion to Mathematics as well as Geometry is already in the concept stage.

The pedagogical concept

The aim is to motivate and support Science teachers so that they incorporate experiments, research-based learning and scientific work in their teaching. The NAWI Center team has set one further goal: It should be mandatory for university students – as part of their curriculum to become a teacher – to do practical work in the NAWI Center with classes or groups. In doing so, students will be able to work with already established as well as self-developed learning units. This process will be supported by the NAWI Center team. Working in the Lerngarten (Learning Garden) is supposed to have direct impact on lessons in class, thus obtaining sustainable quality improvement of scientific education; mere consumption of knowledge is then substituted by science-based and practice-oriented learning. Consequently, attending the Lerngarten has to be part of a major learning unit rather than one isolated event or stopgap.

Organization

For interested in-service teachers introductory courses are offered; in these courses subject-specific as well as methodical-didactic information is provided to prepare for the topics offered. Moreover, information with regard to the organizational procedure is given. Course participation is prerequisite for a subsequent Lerngarten attendance with a class. So teachers wanting to bring their class for NAWI Center inquiry activities will first take part in a preparatory in-service session and then teach their students during a visit to the Center with assistance of experts.

Teachers and students have the possibility to professionalize in techniques and concepts of inquiry based learning. For the teacher education students, it is new, that they can observe teachers, pupils and teacher trainers in a real learning situation, especially without doing the main usual mistake in science teaching: "The teacher gives the answers, before the pupils have the chance to find solutions by themselves." The teachers are prepared without the pupils during preparatory visit. Then the teacher can choose suitable experiments and tasks from the Lerngarten topics. The teacher is provided with adequate material for preparation and follow-up in school. Preparation and follow-ups are fundamental to Lerngarten philosophy.

Subsequently during the visit teachers work with their pupils on experiments and potential solutions in the Lerngarten and are additionally supported by experts from the Center for Teaching Methodology. The teacher is the one responsible for the lesson. The experts assist and provide feedback. The Lerngarten is available for school classes from all over Carinthia from Monday to Friday, from the 2nd to the 41st school week and is free of charge.

Topics

The following topics are currently available for primary schools:

- Magnifiers
- Colors
- Fruits and vegetables
- Forces
- Motion and construction
- Electricity
- Limestone from a biological and chemical point of view

The following topics are currently available for secondary education I and (partly) secondary education II:

- Force – work – power - energy
- Inertia - forces of inertia – mass - comparison of masses
- Why do we believe in atoms? Particle theory
- Experiments with impellers
- Motion and construction

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CHAPTER 7: IBSE IN-SERVICE TRAINING WITH TEACHERS AND THEIR PUPILS IN POLAND

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The Polish educational system promotes higher education; thus also all the teachers, including those who teach in kindergarten and primary school, need to have higher education, including pedagogical preparation. There are two ways to become a teacher in Poland: studying at the pedagogical university or undertaking studies of a particular subject (mathematics, physics etc.) together with university courses of didactics of that subject, pedagogy and psychology. In both cases extensive teacher practice in the schools is required. The whole pedagogical module of the pre-service teacher training combines at least 180 hours of lectures and classes at the university with up to 160 hours of a teacher practice.

In most of the cases such pedagogical courses are old-fashioned. Theory prevails over real practice, hardly any active methods or new pedagogical approaches are introduced. Even young teachers asked[1] about the impact of their studies upon their every-day practice; admit that whatever they learned at the university needed to be put aside when they started working at school. The general opinion is that the teacher preparation is too theoretical. As a result majority of teachers are not prepared to include active methods in their classes. In many cases their subject knowledge is also insufficient. In such circumstances frontal teaching in the schools is preserved from generation to generation.

On the other hand, following the European Union advice, based on the Rocard Report (2007) the Polish Ministry of Education included in a new curriculum, being now implemented in schools, some aspects of IBSE (so called *research attitude*) and a list of obligatory experiments to be performed by learners individually or in groups. Thus in several places in the new curriculum documents one can find such recommendations for class activities such as: hypothesizing, making observations and performing experiments, planning research, recording data, drawing conclusions and presenting them in front of the class. So far however, no systemic teacher training has followed the curriculum reform.

Facing teachers' needs in altering school reality on one hand and having, as the institution, a great experience in promoting active learning by organizing science workshops, lectures and festivities, the Institute of Physics came upon an idea of introducing pre-service teachers to more popular science. For the last few years a

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[1] Data collected while interviewing teachers' perceptions of MST curricula; research done in the SECURE Project, funded by EU under the 7th Framework Programme.

non-obligatory participation in such events has been proposed to replace some of compulsory hours of teacher practice at schools. The biggest events under consideration are: an open-air Science Festival organized every May in the Old City Center and the Researchers' Night taking place in September in all higher education institutions across the city. Students may choose activities they want to be involved in from a variety of possibilities: performing small experiments on a stand or giving workshops to a small audience. The benefits are of two kinds, both leading to student development of pedagogical skills. On one hand, students have to prepare interesting, unconventional activities, independently from curriculum, school routine or judgments of older colleagues, thus becoming more responsible for their work. On the other hand, repeating one activity many times in front of a changing audience, which asks all kinds of questions, makes a student more self-confident and being able to learn quite quickly from their own mistakes. Some students found this alternative very challenging; it occurs that in many cases when they become professional teachers they transfer experience gathered in such events into their every-day practice.

Figure 1 Pupils in workshop

There is a huge need for promotion of IBSE, other active methods and 'learning from different sources' among in-service teachers as well. Thus the National Contest on Science for Primary School – *Firefly* was established by academic staff of Institute of Physics at the Jagiellonian University. In this activity learners are encouraged to perform experiments, make observations, learn about context of science in every-day life and gather science knowledge from all possible sources. Materials used for the experiments are household materials only, so easy-to-get. The contest promotes also analytical thinking and making use of different representations (graphs, drawings, equations, diagrams, tables etc.). Throughout the whole school year teachers together with their classes are encouraged to take part in science workshops organized by our academic staff. The activities are organized by topics, e.g. “Energy in XXI century”, “Ubiquitous electrons”, “Playing with water”, “Mixtures”, “Floating and sinking”, “Spectrometer”, “Magic physics”, “Physics in the kitchen”, etc. The workshops are mostly based on the experiments introduced in *Firefly* contest in previous runs. Most of the activities can be easily adjusted accordingly to the participants’ age. Teachers always have freedom to choose the topic. In many cases they are so enthusiastic after the first visit that they decide to participate in the whole series of workshops throughout the whole year. Thus teachers have an opportunity to observe IBSE activities, to see the management of the group and to experience children’s interest and motivation arising from such events. It has an impact at least on their perception of active teaching, but in many cases those activities also trigger the change of teachers’ every-day practice. The experiences from the Fibonacci Project by the members of staff involved in *Firefly* may not be overestimated.

CHAPTER 8: DEVELOPING A BLUEPRINT FOR INQUIRY LESSONS ON REPRESENTATIONS OF MOVEMENT AND SPEED

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Change is all around us, although we are not always aware of it. In order to understand the world around us it is important to grasp the concept of change. In Dutch primary schools "change" mainly appears in the context of comparing speeds which are represented in 'ready-made' line graphs. Pupils have to interpret the line graphs and draw conclusions about the variables time and distance. Although the reasoning involved can be quite complicated it is rooted in learning tasks stressing only one aspect of speed, namely speed as distance traveled given an amount of time and calculating distance or time when average speed is known.

In this contribution we challenge the conceptual basis on which speed is taught, the way 5th-graders are confronted with graphs as static, ready-made representations. As an alternative we report here a dynamic, inquiry-based and IT-rich instructional sequence on speed where 5th graders grasp aspects of speed ahead of the concept of instantaneous velocity which is taught in secondary education. The questions we address here are: what - if at all - preliminary knowledge 5th graders have about speed? What level of reasoning about speed is feasible for primary school students in an IT- enriched learning environment? And last but not least: what do these experiences tell us about how to teach the concept of speed in 5th grade?

Instructional design heuristics

In secondary education instantaneous rate of change is formally taught as change on an interval as that interval approaches zero. Primary school pupils do not understand the underlying mathematical concepts of functions and limits. Moreover, they lack the necessary algebraic reasoning and skills. So as alternative, calculus-like concepts have to be developed which enable fifth graders to reason about change without appealing to advanced mathematical concepts. An IT-enriched sequence of teaching aiming at understanding pre-concepts or calculus-like concepts of change may fulfill this condition. In such environment graphs can be used as tools to represent change as the co-variation of two quantities.

The presented learning sequence for fifth graders focusses on establishing preliminary understanding of basic principles of change and speed. From a theoretical point of view the learning sequence is the result of design research carried out in order to contribute to a local instruction theory on calculus. This means that the learning and teaching processes involved are based on some heuristics of design based on the instruction theory of realistic mathematics education - RME theory for short - aiming at establishing a coherent network of mathematical and physical mental objects. In this contribution three heuristics of instructional design of the RME theory are described: *guided reinvention*, *didactical* *phenomenology* and *emergent modeling*. In this paper the main focus will be on emergent modeling.

Before elaborating on these heuristics, it is useful to clarify how in RME difficulties in learning mathematics are conceptualized. Learning difficulties are being approached as difficulties in constructing mathematical knowledge of individuals. This is seen as a result of miscommunication between the abstract body of knowledge - which is represented in the textbooks and is being taught - versus experiential knowledge of the pupils.

Freudenthal (1971), one of the founders of RME, being a mathematician himself, aptly remarks that mathematizing e.g. organizing knowledge about reality from a mathematical point of view, resulting from solving problems is the core of mathematics. The final, formal stage of these activities is axiomatizing. Engaging students in the mathematizing processes to invent mathematics and to reach finally the formal stage should be the first concern of math teachers. From a pedagogical-didactical point of view it would be wrong to confront students with ready-made, formal mathematical concepts. One has to consider that it took considerable time, even years of underlying mathematizing activities of the brightest mathematicians to find solutions for these mathematic problems. Students have to construct knowledge by *reinventing* math *guided* by teachers to curtail the process of learning mathematics of mankind (Freudenthal, 1973). Guided reinvention can be seen as a heuristic for designing math instruction. It implicates that the designer should return to the history of math to find out how mathematical concepts were developed over time and what difficulties had to be overcome. For example, he may find that bar graphs were invented first before line-graphs appeared. These findings give a clue how to design a learn sequence.

The second heuristic for designing instruction can be derived from Freudenthal's *Didactical phenomenology of mathematical structures (*Freudenthal, 1983). He describes how mathematical objects of thinking like concepts, procedures or tools can be developed by identifying and analyzing present-day problems and applications. This means that the designer searches for present-day problems which encompass the same phenomena mathematicians in history had to (re-)organize. This heuristic focusses on how to find a starting point for a reinvention route and motivate students to get involved in the problem solving process leading to the formal concepts to be learnt. Present-day real problems form the starting point for the instructional trajectory guiding students from informal to formal mathematical concepts. This process is called horizontal mathematization. Moreover, real problems can derive from questions as: Why does it work? Does it always work? or What general principle is underlying this problem? These questions arise after solving contextual problems with a mathematical structure.

Trying to get answers to explaining mathematical phenomena or finding general rules for observed mathematical phenomena can function as a starting point too. These starting-points are as real as present-day problem situations but reflect a mathematical instead of a practical interest. An instruction trajectory which starts with mathematical problems and questions aims at generalizing findings in a process which is called vertical mathematization (Treffers, 1987). In this process the role of the teacher in fostering mathematical questions is of vital importance. In a design of an instructional learning trajectory questions concerning generalizing knowledge have to be stated explicitly. It cannot be taken for granted that students pose these kinds of questions by themselves.

Emergent modeling is the third design heuristic and is supposed to support the inventions within the process of horizontal mathematization by modeling activities like making drawings, diagrams or tables (Gravemeijer, 1999). During the learning process a gradual shift in modeling takes place from models representing real place and time bound features of the problem situation - so called *models-of*-the situation- towards more general and formal *models-for* mathematical reasoning. The process of inventing mathematics is reflected in the use of the kind of models referring to a shift from a 'referential' to a 'general' level of activity (Gravemeijer et al, 2000). Referential activity means that students derive meanings from their reference to the task setting. Models-for mathematical reasoning reflect students' progress in the process of mathematization of understanding experiential phenomena in mathematical concepts and its relations. The design heuristic of emergent modeling focusses attention on the role of developing a specific math language together with the process of transformation of models (Eerde & Haier, 2009).

Instructional RME-design around the mathematical concept of speed

We outlined the problem of differences in the knowledge of teachers and of students, abstract versus experiential. Three heuristics of instructional RME-design were introduced to bridge the gap between both worlds of knowledge. In this paragraph perspective is changed from a theoretical point of view to practice. An instructional sequence on speed is introduced for fifth graders of the primary schools. It is the result of several try-out sessions in four different schools on the basis of a global theoretical design executed by students of the department of education. In accordance with the heuristic of didactical phenomenology the learning sequence starts with every-day life situations. From a theoretical point of view this is important because it underlines the values of the disciplines involved. In mathematical terms 'numeracy' or 'numerical literacy' (Paulos, 2011) is the objective, enabling citizens to take part in democratic participation processes and if necessary show the power of math in revealing misuse of mathematical tools. An example of this social value of mathematics is the way commercials misuse graphics to promote their products (Figure 1). At a cursory glance it seems that sugar levels within time have decreased substantially. But a closer look at the line graph - which should be a bar graph - reveals that some time intervals on the horizontal axis have been left out, so the decrease of the line is very much exaggerated. Or to put it differently the progress in making the dairy product healthier - less sugars - over the years is not as spectacular as presented in the graph.

Moreover, starting a learning and instruction sequence with ordinary everyday situations is also from a learning psychological point of view of great importance. It is presumed that these situations both engage pupils in the learning process and at the same time function as ‘anchors’ to constitute the basic mathematical and physical mental concepts. If pupils later on in the process of acquiring knowledge encounter difficulties in the process of problem solving or in understanding the big ideas underlying the problem situations they can return to the these anchors or roots by reconstructing the starting situation and the corresponding concepts.

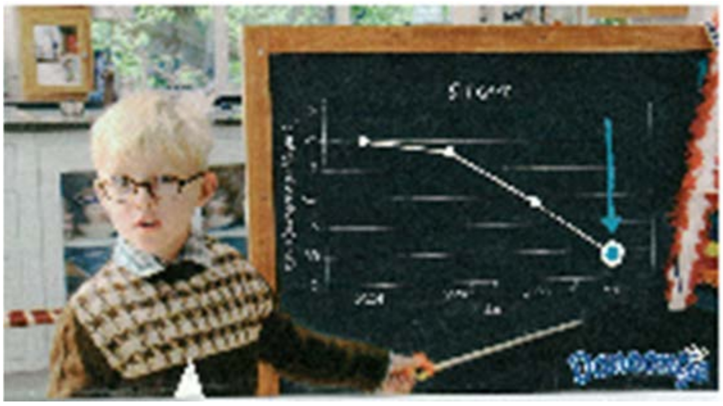


Figure 1 Commercial showing a misleading graph of decreasing levels of sugar content in a dairy product over time.

In the first lesson a context situation of the traffic around school was introduced. Hasty car drivers - sometimes even parents bringing their children to school - cause dangerous situations. Until now, accidents and pedestrian fatalities were avoided. However, this unfortunately could soon be different. Therefore the children were asked how they could know a car was driving too fast. By discussing their suggestions like ‘checking the speedometer of a car’ or ‘measuring the length of the skid marks’, ‘installing speed camera’s’ or ‘building speed bumps to decrease the speed’ the children were finally not really convinced that the found an easy solution to the problem. This introduction was meant to evoke awareness of the concept of speed. After this introduction a video clip was introduced showing cars driving along the school with clearly different speeds. At the same time right under the car a bar was shown representing the car’s speed. By comparing the speeds of the cars the children concluded that faster cars were accompanied by longer bars (Figure 2).

Figure 3 shows an overview of the problem situation the fifth graders were confronted with in lesson two, showing the displacement of a train along a twisty railroad track. The train starts at the departure station ‘Yellow’, accelerates, slows down, stops at the intermediate station ‘Red’, accelerates once more but faster than before, slows down and finally stops at the end station ‘Green’. As you can see in Figure 3 strips of paper were positioned along the train trajectory to remind children of the bars keeping up with the speed of the cars in the videotapes. The strips were meant as a hint for drawing a picture of the moving and stopping train, so anchoring this way the setting of the train in the proceeding setting of the cars.

Figure 2 A car driving along the school. Its speed is represented by a bar extended every second to show the relationship between speed and distance traveled.

The problem of Figure 3 was posed by the teacher: how can you make a drawing of the train moving from the starting point to the end station without losing any information and by using as little language as possible to describe what happened? The children were engaged in 'telling the story' (Berg, 2012) in a drawing representing all the episodes of the event. The drawings can be seen as graphical representations. They show the difficulties of making connections between kinematical concepts, their graphical representations and the motion of objects. Important to notice here is the extent to which the 'graphs' are connected with visual characteristics of the situation that has to be represented.

Figure 3 Fifth graders watch the train running down the rails.

Figure 4 A drawing of fith grader Sylvana as an example of the first stage of emergent modeling called a model-from-the-situation showing all kinds of visible details.

Figure 4 shows the drawing of Sylvana and the solutions she chose to solve the problem of representing the changes in speed of the train. Station 'Yellow' as the starting point, the intermediate station 'Red' and the end station 'Green' are pointed out very clearly. The difference in distance between the first trajectory from the beginning to the intermediate station and the second one is quite clear too. Sylvana's drawn rail track shows different colors explained by means of a legend. In her drawing blue means 'slow', red 'fast' and green refers to 'average speed'. She seems to have no solution for representing the episodes and the train shows no displacement.

Figure 5 shows the drawing of Hans. It is more a film of the episodes which happened during the rail journey each symbolized by a steam locomotive. Differences in speed are symbolized by bars of different lengths underlined with terms like 'slow' and 'fast'. The faster the train runs the longer the bars, just like demonstrated in the video clips of lesson one. Moreover by means of short parallel lines behind the train he emphasizes the top speed like is done in comic strips. Hans has however the same problem as Sylvana and could not find a solution for representing the stops of the train.

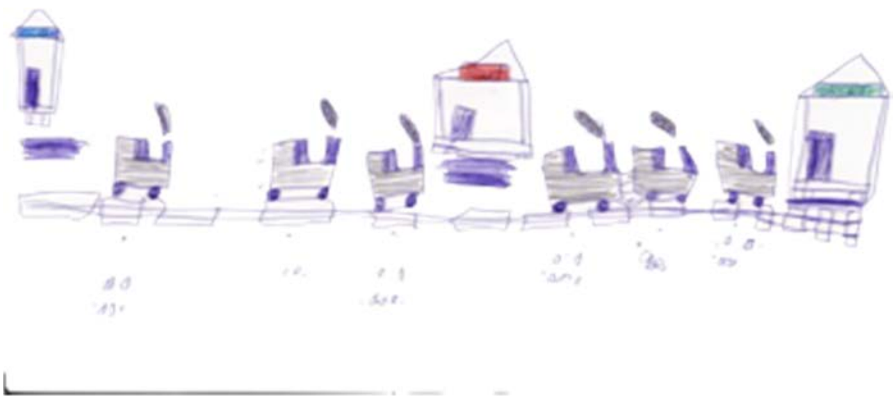


Figure 5 A drawing of Hans as an example of the first stage of emergent modeling called a model-*from*-the-situation showing all kinds of visible details.

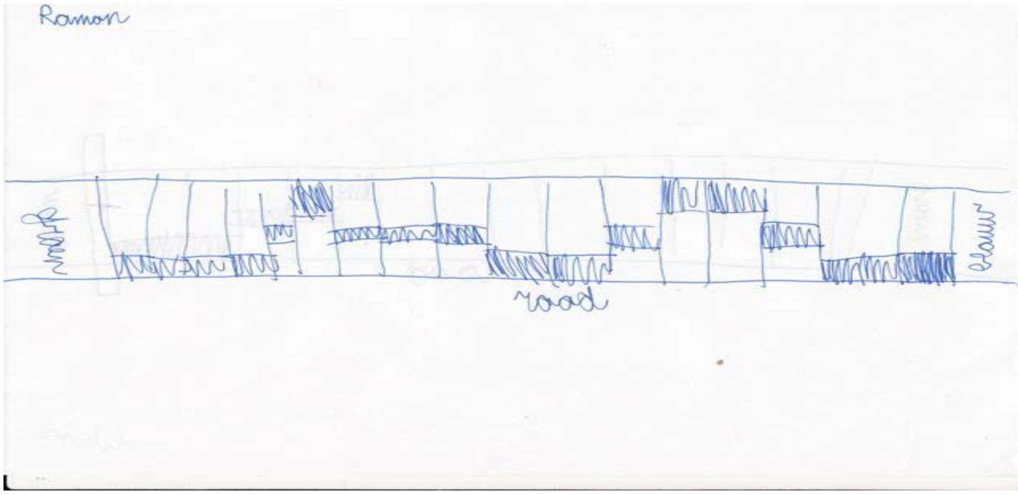


Figure 6 A drawing of Ramon as an example of a drawing reflecting more aspects of a model-for-the-situation as the stage of emergent modeling showing notions of conceptual aspects as the co-variation between time and speed.

Figure 6 shows Ramon's drawing. Features of a kind of bar graph can be seen: a horizontal axis representing time and a vertical axis representing speed. The bars at the bottom show that he does have a solution for the moments the train shows no displacement. Compared to the drawings of Sylvana and Hans, Ramon's drawing shows more features of a model-for-reasoning because the co-variation between time and speed is clearly reflected. Assigning labels to the axes turned out to be too difficult.

In the third session of the learning trajectory the fifth-graders had to compare the speed of three battery driven toy-racing cars. After a classroom discussion how to compare the speeds of the cars it was decided that the speed of each car had to be measured by means of a strip of paper on which 'distance' had to be marked every three seconds (Figure 7).

Groups of three pupils were formed. One of them drove the car along the strip of paper while the second one counted up till four repeatedly, and the third member drew a line on the paper at the moment the second member pronounced 'four'. The group results of the measurements were compared but delivered no satisfying figures. The speed measured as 'total-distance-bars' of the same toy racing car turned out to be inaccurate. After a discussion guided by the teacher the class agreed that the conflicting outcomes were caused by the inaccurate way the distance time intervals were recorded on the paper strips. So it was decided to use an adjustable sound signal on a tape as a trigger to draw a line on the paper strip every three seconds. This was done by two of the three group members out who drew the lines after each interval alternately. The measures of the distance traveled represented by the bars over the groups showed less variance and appeared much more accurate.

Figure 7 Comparing the speed of toy racing cars by measuring the total distance within a time interval by means of strips of paper.

This lesson stresses the importance of introducing and developing a common math language like the term 'total-distance-bar' which derives its meaning from the context of comparing the speed of cars indirectly by the total distance traveled within each time interval. The same holds for terms like 'accuracy', 'measuring errors' and 'time interval'. Moreover, the social-cultural aspects of learning become apparent. Working together and discussing outcomes with each other can generate solutions for the problems encountered. Without the careful preparation and the guiding hand of the teacher these 'discoveries' in practice would take much time if discovered at all.

The step towards a graph representing speed was made in the fourth lesson. The strips of papers of the toy cars were cut into pieces, each piece showing the distance traveled of a car within an interval of 3 seconds. This activity was articulated as cutting into pieces the 'total-distance-bar'. The 'sliced' bars were turned into a vertical position and were put alongside one another (Figure 8). This configuration was called the 'pieces-distance-graph'.

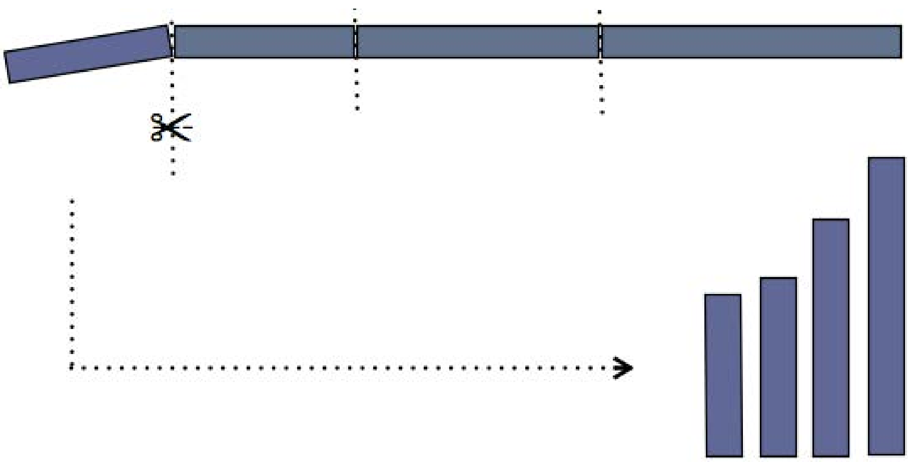


Figure 8 Transformation of the 'total-distance-bar' into a 'pieces-distance-graph'.

The 'pieces-distance-graph' or displacement graph (figure 8) can be seen as a model representing the speed of a car. The faster the car, the greater the distance traveled within the time interval. The next phase of the instructional design, the fifth lesson, shows the follow-up of the modeling activities in an ICT-enriched environment (Figure 9). Just like before, the mathematics continues to be related to students' understanding of the physical properties of motion and efforts are made to keep the follow-up activities connected to earlier experientially real, everyday-life phenomena.

The shape of the graph models the ever changing correspondence between the values of the quantities time (horizontal axis) and distance traveled (vertical axis). Moreover every bar added to the graph on the left is depicted separately on the right showing the distance traveled between two moments of measuring. The graphs the computer produces reflect the dynamics of the changing values of the quantities involved.

With distance, time and speed all kind of graphs can be generated. As can be read from the maximum length of the bars at the end of the graph Figure 10 depicts a 'total-distance-graph. A series of bars with the same length along one another tell us that the train halts at these moments. To put this in another way the distance to the starting point is not altered, so the speed is zero at that time.

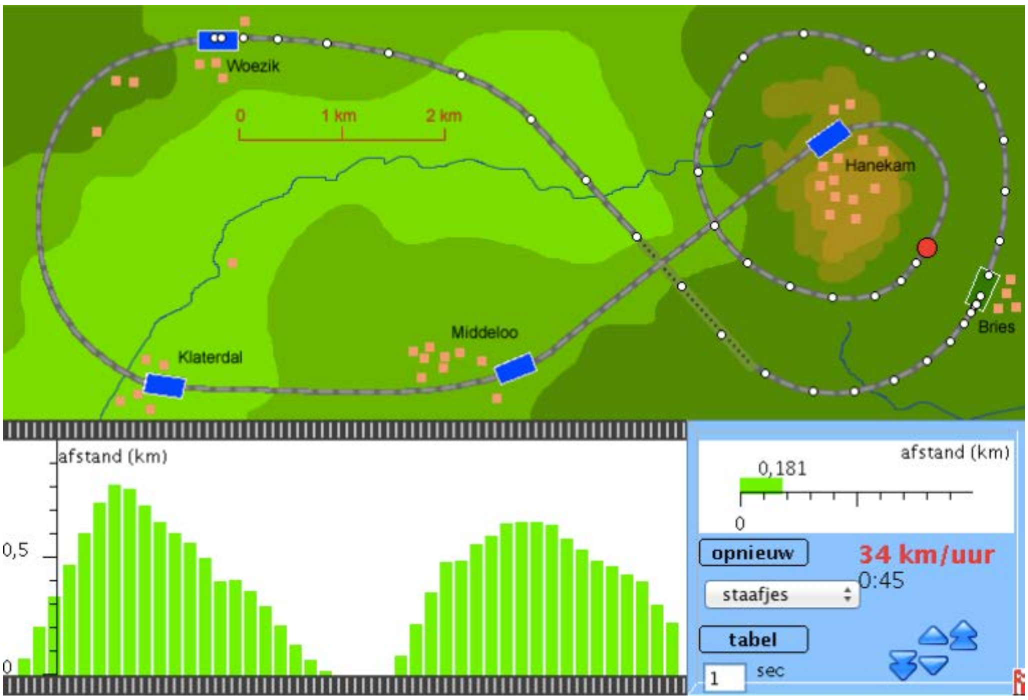


Figure 9 Pieces-distance graph. Every second the computer generates a bar: the distance traveled by the train within the interval.

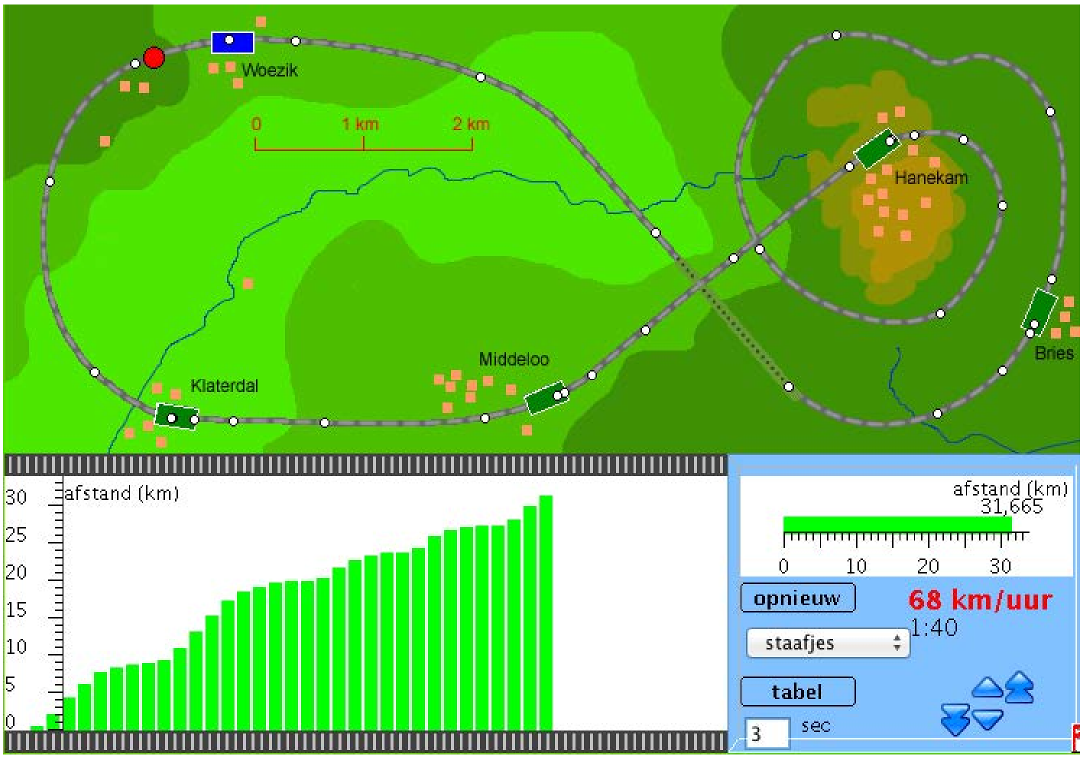


Figure 10 Total-distance graph. The height of the bars on the right of the graph show the train is near the town of Woezik, the end station. On the right the horizontal bar shows the distance traveled so far: 31.665 km..

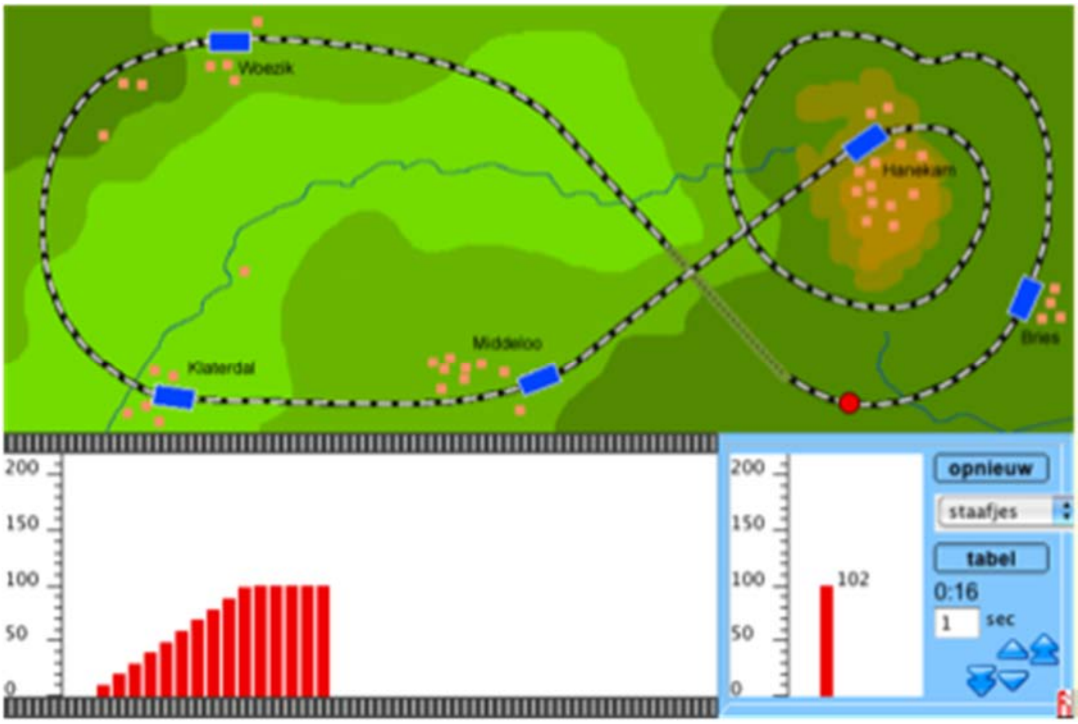


Figure 11 Graph of the speed of the train.

Finally a third kind of graph can be generated. Figure 11 shows every instant the graph of the speed of the train. It depicts the change of value of displacement per time interval (speed). The differences in length of the first five bars in the graph of Figure 12A tells the story that the train during this interval accelerated, next the speed is constant for a little while, and then the length of the bars goes up again signifying further increase in speed. In Figure 12B the line graph shows differences in the slope of the lines, pointing out differences in acceleration. However, articulating, interpreting or reasoning on this abstract level seemed too difficult for the fifth graders. The bar graphs evoked less superficial statements around the steepness of the lines. The statements were more concrete like ‘the first bar shows the train is going 10 km per hour, the second bar even more: 20 kilometers per hour.

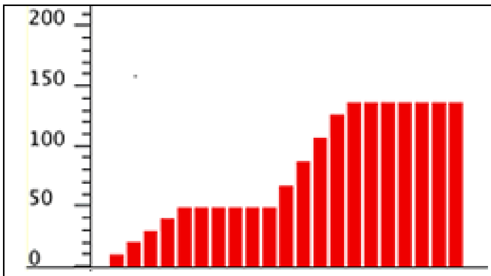


Figure 12A Bar graph

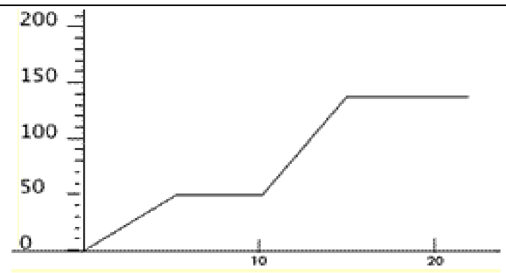
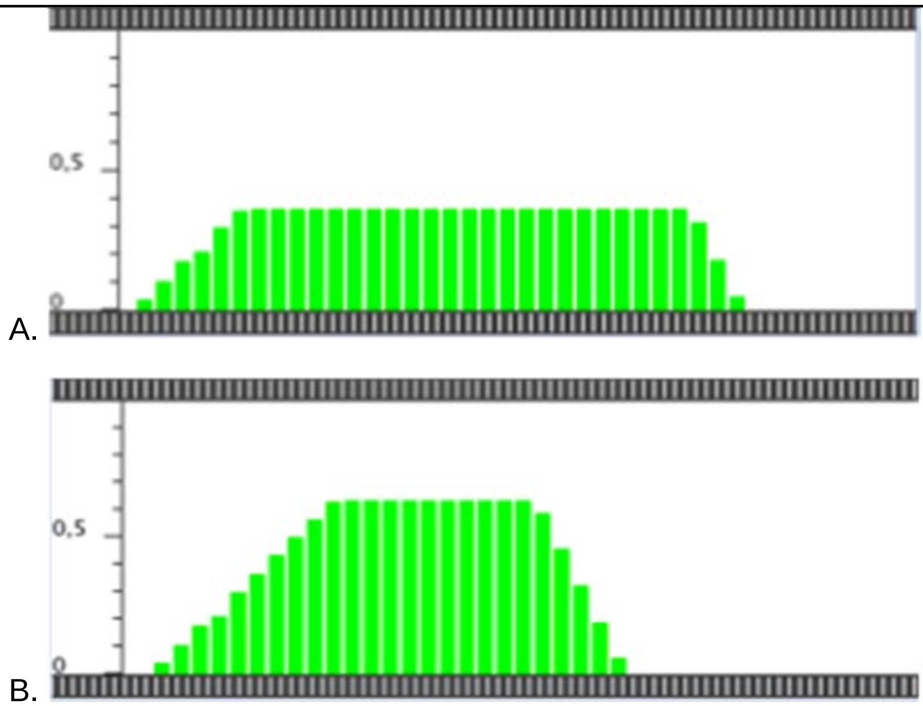


Figure 12B Corresponding line graph



Compare graph A and B
Which graph A or B, depicts that the train has traveled the *longest period of time*? Explain.
Which graph A or B, depicts that the train has traveled the *longest distance*? Explain.

Figure 13. Some examples of learning tasks within the digital learning environment ‘the train driver’.

After this introduction the different graphs themselves were the instruments of reasoning. All kinds of questions had to be answered. Like ‘What does it mean the length of the bar graphs increases or decreases?’, ‘Can you explain why the length of the bars of the ‘total-distance-graph’ decreases and the bars of the ‘pieces-distance-graphs’ goes up and down? Is it possible to make out of a ‘pieces-distance-graphs’ a ‘total-distance-graph’? Is it possible to this the other way around? Figure 13 gives some more examples of the questions the fifth graders had to answer.

Conclusions

Which preliminary knowledge do 5th graders have about rate of change? As was pointed out the contribution of math textbooks to understanding graphs in the context of change is limited. As noted, Dutch math books focus too much on interpreting graphs in terms of ‘finding the right answer’. In math textbooks pupils are not challenged to build their own models of a situation, and are not involved in discussions about the intentions and meanings of the models.

The result is that the fifth graders in general have only superficial knowledge at their disposal. To illustrate this point we asked them whether they thought it was plausible to drive a car with a speed of 80 km/h to school. Many children were convinced this was impossible, reasoning the route to school just was too short: “From home to school cannot be a distance of 80 km” or “You don’t need to drive an hour to arrive at school”. Vague notions of the concept of ‘average’ speed seemed part of this reasoning. This is due to the fact that textbooks or teachers in this context stress the procedural aspects of calculating the mean. In this context abstract and static models like ratio tables are used to get quantities like distance, speed and time. Moreover from a scientific and technical point of view it turned out that measuring instruments like speed trap cameras were well known, though most of the children did not have the faintest idea about how these measuring apparatus work or what is in ‘the black box’.

Our experiences with this learning trajectory based on three RME-design heuristics show that the fifth graders can reach quite sophisticated levels of reasoning if they are challenged to discover and reinvent the mathematical concepts. The IT-enriched learning environment together with the different and diversified problem situations are credited for the enthusiasm and the motivation of the fifth graders. However the teacher, the interaction with the group, the kind of questions posed are very distinctive factors in this environment. Organizing this particular kind of lessons with re- invention of mathematical concepts is not easy. It turned out to be very demanding to enhance the thinking and reasoning of children on a conceptual level together with adequate feedback at the right time. The design heuristic of emergent modeling together with the development of a specific math language seems to be very helpful. However, there are some limits. This can be derived from the difficulties the fifth graders had in solving problems like that of Figure 14. At least as they were presented in a line graph.

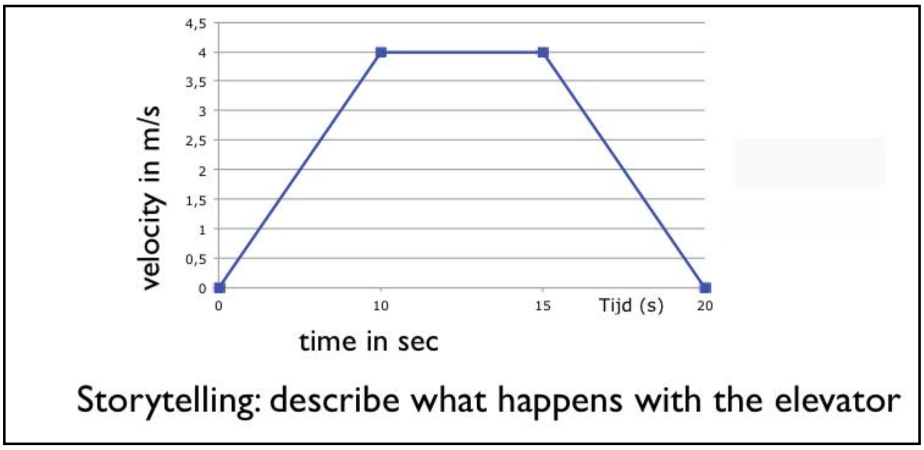


Figure 14. Test item interpreting a speed graph

So open modeling activities to 'invent' models, representations and meanings, reasoning what model(-s) fit the situation best and why, seem to be important requirements to enhance conceptual development and prevent problems. Further research is necessary. A follow-up instruction trajectory has been designed to develop the level of reasoning around the concepts of time, speed, distance, velocity and motion further (Gravemeijer et al, 2012).

Teacher Education Students and Innovation

The research in the accompanying article produced a learning trajectory for graphs and rate of change, however, it is intentionally an outline rather than a recipe to be followed step-by-step. The outline still has to be tailored to the school and the pupils. How can this be used to train pre-service students in facilitating inquiry lessons? Six pre-service students participating in a Minor Math Education implemented this in 6 grade 5 classes in 3 different schools. They first participated in a training on how to teach math using so-called "rich" problems, that are context-rich problems which can be solved in different ways. Then they studied the outline and the rich math problems to be done by the children. Subsequently they started the series of lessons in their internship classes.

For every lesson one pre-service student took the lead and taught the lesson first in his/her school. After the lesson the six pre-service students together with the researchers would discuss the oral report and video clips of the lesson and make revisions and suggestions. Then the five other pre-service students would implement the lessons in their own classes. Every following lesson from the series another pre-service student would be in the lead. Initially the researchers were leading in the discussions; however, as the lesson series progressed, the role of the pre-service students in the discussion became more and more prominent as they became the experts of classroom experience.

With advancing of the discovery lessons the motivation of the children increased and they became more and more enthusiastic about it. Also the students experienced these lessons as challenging and very enriching events. These yields were clearly observed by the mentors. As it turned out school principals became aware of the enthusiasm and motivation of the pupils during the discovery lessons. Afterwards they stated these lessons were inspiring examples of good practices of math and science for the future.

From the perspective of teaching education the here presented learning trajectory shows a promising setting of connecting theory and practice, enhancing knowledge of pre-service students and learning them how to apply this in practice in a meaningful way. For teacher educators it is both enriching and inspiring to be involved in a process of pre-service students connecting formal knowledge with informal knowledge of the domain and their practical experience.

Figure 15 An implementation and training project with pre-service students

Unfortunately such training with so much attention to pedagogy of content knowledge (PCK) cannot be done with all pre-service students as the required guidance can only be provided on a small scale. However, as teacher educators we should keep looking for opportunities to enrich pre-service students' experience with PCK and there are often more opportunities than we think, particularly in projects promoting IBSME such as Fibonacci.

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