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A SUSTAINABLE TEACHER TRAINING: APPROACHING MORE SCIENCE CONTENT AND INQUIRY

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Abstract: How can teachers change the way they teach so students get access to more features of inquiry based science teaching and learning? Four teacher educators and researchers worked with five teachers from two schools, to develop tools to analyze teaching sequences. The teachers’ lessons were video-taped on two occasions at least with several weeks in between. The films were analyzed and various didactic issues discussed in seminars with the researchers and the teachers. After the first lesson feedback, the teachers were given the challenge to make a teaching sequence paying regard to his/her reflections on our seminar and our analysis of the first lesson. We report a case study in which a teacher, Roy, develops his teaching in several respects such as dialogic communicative approaches, writing, and science content. We compare and analyze two of his lessons: the first on Electricity and the other on the Water Cycle. The teacher Roy is able to create interesting lessons in which argumentation and debate are included. With the second lesson Roy showed awareness of the significance of the science content in the dialogue, and he gave a greater subject-matter depth compared to the first lesson, as well as a wider variety of scientific ways including experimental work. The science content was, however, superficial and vague in both lessons. The difficulty of meeting the students in dialogue occurs when the teacher’s own knowledge is insufficient. The teacher’s awareness of the importance of dialogue in the classroom combined with a greater depth of subject focus, lead to learning opportunities for students that are of benefit for both language and science skills.

Keywords: communicative approaches, teachers professional development, dialogic inquiry, inquiry-based science teaching/learning, writing in science

INTRODUCTION

Teacher training in the form of short-time courses or teachers’ seminars with lectures have been shown to have limited success concerning the teachers’ reception and implementation of new ideas and skills in the classroom, and over time. The research literature concludes that effective teacher training in contrast to the ‘one-shot workshops’ or ‘top-down cascades training’ must be characterized by 1) the teachers helping each other with school activities, and 2) an emphasis on self-instruction and opportunities to practice in a context where the teachers are active and choosing their own goals, and 3) training ongoing over a long period of time 4) support, demonstrations and feedback. (Adey, 2004; Schwille, Dembélé & Schubert, 2007)

This paper presents a case study from science teaching in a Swedish compulsory school. Four teacher educators and researchers have cooperated with five teachers from two primary schools, to develop tools to analyze teaching sequences that will be used as material for reflection in new teachers professional development programs (TPDPs). We have an approach
of working with teachers as a ‘community of practices’ (Wenger, 2004), into which the researchers bring knowledge from the research community. The teachers bring the contextual knowledge about the class, the background to the teaching situation, the possible level of framing the science content of lesson, limitations and strengths that are present in the actual situation for the teaching and the relation to the curriculum. We focus on one of the teachers, Roy, and the way he consciously varies his teaching towards dialogic communicative approaches including writing, and the way he frames his teaching in aspects of science content. When working with Roy and his colleagues, we showed and referred to domain-specific instructional theories in research literature. By introducing examples from such literature, the teachers got engagement and inspiration to give priority to science content of teaching in the classroom. The ownership of the final design of the teaching–learning is always in the hand of the teacher, which we find obvious, but needs to be expressed and argued for.

AIM AND RESEARCH QUESTIONS

The overarching objective is to build a sustainable teacher training in science by letting schools and researchers work together for a long period of educational development, and through TPDPs introduce inquiry-based science teaching / learning to stimulate students’ engagement in science and technology. Another aim is to challenge the teachers to create science-based lesson sequences in science and technology built on increased awareness of communicative and dialogic approaches in their science classes.

In this paper we like to answer the following research questions:
- What researched-based activities did the teacher use in the lessons?
- How is the lesson time spent on different types of activities?
- What types of communicative approaches are used?
- What lesson activities allow dialogue?
- How is writing used as part of the dialogic science discourse?

THEORETICAL BACKGROUND

Our intention to create ‘sustainable’ teacher training, means that we want teachers to get research-based information that help them look upon their classrooms with new eyes. We find it plausible that teachers with a changed view on teaching/learning are themselves able to create a new learning environment in the classroom. Adey (2004, p.169) argues: ‘Successful implementation of innovative teaching methods through professional development requires a combined approach, providing teachers with information, guidance, and leadership while recognising that no outsider can impose a model.’ Our aim is to inspire teachers to develop a dialogic inquiry based science teaching/learning, in this study guided inquiry (Guesti, 2008). Dialogic inquiry takes departure in the view that fundamental for dialogic classrooms is the students having self-confidence, and there being trust and respect among students, and between students and teachers. Therefore, the feedback given from teachers and other students is essential. Students with different backgrounds, different languages, and experiences create the classroom environment. Different opinions clash and lead to further development of ideas. A dialogic teaching requires that students can join in a dialogue with the subject matter, which can usefully be made in writing. This special form of dialogue can also be found when students work in small groups and use exploratory talks (Barnes & Todd,
to find the answer to a specific question. Episodes that include dialogic inquiry also mean situations when learners and teachers together explore ideas that are not planned for the lesson, but are initiated by the way the dialogue has taken place during the classroom discussion, for example by students self-generated questions.

Mortimer and Scott (2003) developed a model for the scientific conversation in the classroom in their book *Meaning-making in secondary science classrooms*. The teacher’s approach to the talks can be studied in the dimensions of interaction / non-interaction and authoritative (mono-logical) / dialogic. With this model, the conversation can be analyzed by using the talk chains built up. The triadic conversation IRE (initiation-response-evaluation) is typical of the monologue / interactive call. The IRE pattern is often built on question-answer-evaluation, when the teachers make the students “que-seekers” the pupils guess the word the teacher is aiming at. This pattern is distinguished from the dialogic interactive IRFRF pattern (initiation-response-feedback-response-feedback), in which students get more space. The IRFRF pattern of discourse can be found when the teacher instead of asking yes/no questions, encourages and prompts the pupil to tell the class of personal ideas around the phenomenon that is in focus. Mortimer and Scott (2003) emphasized that teachers’ awareness of these different approaches could help them vary between different approaches in an appropriate way. They described further on, the teacher’s responsibility to: 1) present the scientific ideas on the social plane, 2) discuss the ideas with the pupils to help them internalize the ideas, and 3) hand the ideas over to the students to make them their own. In our seminars with the teachers we also discussed principles of dialogic teaching based on Alexander (2004).

Writing is a powerful dialogic means and a tool in the learning process, that makes the student sharpen the thinking and in an intelligent manner use appropriate concepts. In the international writing research there are two main directions, both of them dialogic means but in different ways. One direction, *Writing Across the Curriculum* (WAC), stresses writing-to-learn-strategies, which can be used in all subjects. Spontaneous writing and writing to investigate can help the pupils “make the content of the subject their own”. This kind of writing can be used in various ways in short “mini-writing” tasks such as: What do you know about…? What is your opinion of…? What solution do you think is best? Why? These texts primarily serve as the student’s thinking tool, discussion and dialogue in groups. The other direction, *Writing in the Disciplines* (WID), stresses the terminology of each subject, its linguistic style and requirements of the subject specific genres, for example the lab report in natural science. In this kind of writing the student’s text has a reader, which is more demanding than writing for his/her own thinking.

**METHOD**

Through presentations in a seminar series on science education, four teacher educators and researchers made contact with primary school teachers, who were interested in participating in individual training with mentor support, to develop science teaching. Two primary schools and five teachers volunteered to join the project. Initially the teachers were interviewed. The teachers’ lessons were video recorded and analyzed. In seminars feedback on the analysis of science content and communicative approaches was given as well as lectures on teaching with a dialogic approach. Oral and written orientation on recent research was given. After the first lesson feedback, the teachers were given the challenge to make a teaching sequence paying regard to his/her reflections on our seminar and our analysis of the first lesson.
The teacher we follow in this case study, Roy, taught two grade 5 classes (students 10 – 11 years of age). In this presentation we analyze and compare two of the lessons in his class: the first introducing electricity/energy, the second dealing with the water cycle. The lessons have been analyzed in terms of activities, science content and writing. We use the structure for a ‘design brief’ described by Leach, Ametler & Scott (2010) to follow how Roy implemented the teaching sequences leading to the lessons The Water cycle and Electricity.

Description of the context for the designed teaching

The Swedish Curriculum of 1994 (Lgr 94) was in use during the project period (in August 2011 a new curriculum for the Swedish compulsory school was introduced). The purpose of the physics subject, as described in the curriculum, is based on students' desire to know more about themselves and the world. Particular attention should be paid to the teachers actively helping the students achieve understanding. At Roy’s school there are many qualified and experienced teachers, but like Roy, some of them lack science in their teacher qualification. The school has a special task to work with students with Swedish as second language, and up to 75 percent of the students come from non-European countries.

The pedagogic strategies and sequencing of content to be used in Roy’s teaching are: Staging the scientific story, Supporting student internalisation, Handing over responsibility to the students and Design tools.

In order to analyse the lesson activities, the videos are categorised (with time as unit of analysis) with the help of computer programs (Videograph, SPSS), and the percentage distribution of class time on 1) teacher's instructions, 2) scientific discussions, 3) problem solving with the investigation, 4) writing tasks and 5) small-group work. Furthermore, Roy’s use of different communicative approaches (Mortimer & Scott, 2003) was categorized in a scheme for dialogic inquiry: interactive dialogic, interactive authoritative, non-interactive dialogic and non-interactive authoritative. The scientific content is categorized into concepts, applications, larger context, and socio-scientific issues. Analyses of Writing Across the Curriculum (WAC) and Writing in the Disciplines (WID) were made, as well as oral and written elements of argumentation.

RESULTS

The lesson on electricity, which we video-recorded and discussed in our seminars with the teachers, lacked full clarification of scientific concepts, it contained no experiments, and no writing. The external environment was presented with a video on hydroelectric power and later on also other sources of energy production were discussed. The lesson ended with a value-training task in which the students were asked to vote for which kind of energy supply they preferred: nuclear power, wind-power, waterpower or solar power.

In the following we are focusing on the second lesson, the lesson on The Water Cycle, where we saw many examples on interactive/authoritative talk as in this situation reviewing an earlier lesson:

Roy: You remember last Friday we started to do a water test. What did we do, Amanda?
S7: We had four glasses that we filled with water. So we put one on the shelf, one on your table, one below the electric heater and the one under the sofa.
Roy: Why did we do it? Why do we put a glass of water at different places?
S7: To check if it had evaporated.
Roy: Evaporated. Let’s check what has happened to the four glasses. We talked about some other things about water, too. I'll write down some key words that you should have in mind today, so you remember what they mean.

Now the students are asked to write down everything they know about the water cycle. After five minutes they discuss in groups of 3-4 students and close with a presentation where each group explains what they come up with. The teacher gives a summary of statements as he draws the sun, water waves and arrows on the blackboard:

Roy: We have a sun, which warms. This is a sea (drawing) - it will conduct heat from the sun (draws stretch down from the sun to the water) - it evaporates water from the water surface (arrows are drawn up from the water surface). We have the energy needed to heat the water. It rises. What rises? Do you know what it’s called?

S1, S2: Steam. Water vapour.
Roy: Yes, and it's a gas. What happens to the water vapour, then?
S2: It goes up to the clouds.
Roy: The formation of clouds of gas is up here. Does it start to rain at once?

One of the problems we face in the conversation above, is that the teacher is not aware of the difference between water steam and water droplets. He draws two clouds on the blackboard to illustrate a cloud with ‘gas’ and a cloud with water-droplets. The conversation starts as interactive/authoritative, but gradually becomes interactive/dialogic. The atmosphere in the classroom opens up for student generated questions:

S4: Cool! It's a weird thing I have always wondered about. Why is the snow white?
Roy: Why is the snow white?
S4: Yes, just white.
S1: It may well be yellow too.
Roy: (all laugh) Yes, if somebody has peed on it, yes. I don’t know why the snow is white, it's some kind of crystals that reflect, I really do not know. The ice crystals are white.

The lesson continues by checking from which of the glasses the water has evaporated the most, and to write down the results into a template for a laboratory report with the headlines: water cycle, evaporation, condensation, energy. A last brain-storming started by writing in log-books on the question: Will water evaporate at any other places than rivers, lakes and oceans? After the following group discussions the teacher summarizes what the students have come up with:

Roy: It is your breath. It is hot, then it .... water vapour.
S6: In a sauna, it will be like really hot when you blow on himself. . But when one blows here all is just normal.
Roy: Yes. What more needs water to survive then? Do animals evaporate? Is the only place it evaporates from when doing so? (Roy breathes hard.) Amanda, you can see your breath when it's cold outside. (Makes a gesture from the mouth to show the breath). Is it the same thing in here though I do not see it? Is steam coming out? Have you done like this with a mirror? (Blowing against the palm to illustrate). How is it then? (Several students rush to respond).

Foggy, misty. What is this?
Roy: Water vapour.

The communicative approach has become even more interactive/dialogic, as student experiences are told and discussed. Unfortunately the same teacher’s view on water steam as water droplets make the science content questionable. The lesson concludes with an experiment that is described in the logbook – the evaporation from the hand put into a plastic bag and sealed with a rubber band.
In table 1 the communicative approaches in the two lessons are compared. The intention to enhance the dialogue towards dialogic interaction has been successful with an increase from 40% to 60% between the two sequences.

**Table 1: Percentage distribution of time for different communicative approaches**

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Interactive/authoritative</th>
<th>Interactive/dialogic</th>
<th>Non-interactive/authoritative</th>
<th>Non-interactive/dialogic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity/Energy</td>
<td>47%</td>
<td>40%</td>
<td>11%</td>
<td>1%</td>
</tr>
<tr>
<td>The Water Cycle</td>
<td>16%</td>
<td>60%</td>
<td>23%</td>
<td>0</td>
</tr>
</tbody>
</table>

In table 2 is shown how the natural science content is distributed quite differently between Roy’s first and second lesson.

**Table 2: Percentage distribution of time for the science content divided into categories**

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Concepts</th>
<th>Application / Natural Phenomena</th>
<th>Wider context</th>
<th>Socioscientific issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity/Energy</td>
<td>4%</td>
<td>51%</td>
<td>37%</td>
<td>9%</td>
</tr>
<tr>
<td>The Water Cycle</td>
<td>92%</td>
<td>7%</td>
<td>1%</td>
<td>0</td>
</tr>
</tbody>
</table>

Analysing the kind of science content focused in the lessons, we see in table 2 four categories. The science concept part has increased considerably in the lesson that was inspired by dialogic teaching, but all broader contexts have a remarkable decrease.

In table 3 below is shown how Roy used writing as a dialogic learning tool in his science classroom.

**Table 3. The use of writing in Roy’s classroom**

<table>
<thead>
<tr>
<th></th>
<th>Lesson I Electricity/Energy</th>
<th>Lesson II Water Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Writing as a thinking tool and a basis for discussion</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Writing of specific genres</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Reporting facts in full sentences</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Reporting a course of events</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Arguments supported by facts reported in full sentences</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Use of specific concepts</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

As can be seen in table 3 there is a big difference as to the use of writing between the two lessons. In lesson I no writing tasks were given at all, while it was an important element in the lesson on the Water Cycle. Roy used writing as a tool for thinking and as preparation for group and whole class discussions, which made the students feel safe and free to express themselves. He also used writing in the lab reports – a very specific genre of natural science, which the students must gradually learn to master.
DISCUSSION AND CONCLUSIONS

During this collaborative project more dialogic elements were included in the lessons in which student questions were discussed and the content problemised. The students were given greater autonomy to express their thoughts, and to participate in a dialogical conversation, both oral and written, with each other and with the teacher. The academic language of natural science was focused, and the students got greater opportunity to expand the vocabulary of scientific concepts. The teacher increased the amount of interactive dialogic conversation, and used inquiry and experiments in several lessons following on each other. The teacher had, by adopting the theoretical frameworks afforded, changed his view on dialogic aspects in the classroom, and on the importance of language for students to become disciplinary discourse participants. New words and concepts are provided to the students by talking and writing exercises – and emphasise is on letting the students express their own ideas and questions. Experiments were planned and guided inquiry gave high engagement among the students. A sign of learning is the relevant questions, which could be seen also in the writing tasks.

In this case study the collaboration between teachers and researchers is built on the teachers’ ownership of the teaching content, which is allowed to vary widely. Focus on learning objectives and subject content is strong. The teachers’ awareness of their own communicative approaches, of the science content being varied between concepts, applications and broader contexts, and of science writing as a dialogic means, are other important factors. The students had to use the new concepts of the water cycle in several ways, in listening, in writing, in oral, and also by drawing in their lab reports. Consequently, Roy’s use of writing as a dialogic and learning tool connects to both the WAC and WID research directions. By varied linguistic use the students strengthened their knowledge.

The teacher Roy is able to create interesting lessons, where argument and debate are included. The science content, however, was in the first lesson superficial and vague. With the lesson on the Water Cycle the teacher showed awareness of the significance of subject content. He was able to give a greater depth and more variety of scientific ways of working and experimental moments. The difficulty of meeting the students in dialogue occurs when the teacher’s own knowledge is insufficient. However, Roy, who is not formed by the science education ‘canon’, has much to teach us about science teaching in risk of becoming too narrow. We are convinced that this teacher has new tools to work with in designing new lessons, and an interest to enhance his own science understanding, with the positive response his students gave him.

We see a great need for more subject knowledge, which cannot be met by simply increasing awareness and use of our tool for analysis of educational content. With the teacher’s experience of dialogue in the classroom and a greater depth of subject content, rich opportunities for students’ learning that benefit both the language and science skills would be created. We maintain that the training model described above has the potential to support teachers’ learning. A TPDP needs to provide meaningful learning that takes into account the aspects discussed. There is evidence in the literature that the model we are developing together with the teachers delivers the key components necessary for an effective teacher training that leads to teachers learning. We believe that by not only disseminating teaching ideas, but also participating, and by supporting the individual teacher and the team during the implementation and development of ideas in the teacher’s own learning environment, we help the teachers to revitalization and increased motivation.
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