RESI DAMHUIS AND AKKE DE BLAUW

15. HIGH QUALITY INTERACTION IN SCIENCE AND TECHNOLOGY EDUCATION

How teachers link cognitive and linguistic development

INTRODUCTION

This chapter describes the approach of incorporating high quality interaction in science and technology education, employing interaction as indispensable tool and strategic purpose simultaneously.

First we argue why high quality interaction is vital in science and technology education (S & T education). We describe the concrete features that mark high quality and demonstrate why high quality interaction needs to be incorporated in teacher professionalization. Next we focus on research findings that show how teachers are actually able to learn to realise the desired interaction in S & T education. The findings result from small scale quantitative studies and from a qualitative description of an S & T lesson.

INTERACTION IN SCIENCE AND TECHNOLOGY: HANDS ON, MINDS ON, TALK IT OVER

In science and technology education the popular adagio is hands on, minds on (introduced by Driver 1983). We will argue here, that this adagio lacks a third component. Although ‘minds on’ implies to ‘think aloud together’, our work with practitioners has made clear the need for an explicit statement. Children need ample and high quality opportunities to talk to others, i.e. peers and teachers, about discoveries, ideas and solutions. Without such opportunities science and technology education will not reach its goals. So we propose an extended adagio: hands on, minds on, talk it over. This adagio could also help to avoid the trap of the so called ‘pseudo-inquiry’ (see Harlen & Lena, chapter 1): plenty of practical activity, but a lack of involvement of the children in making sense of phenomena or events in the natural world (italics by the authors). The proposed extension is grounded in two major theories: socio cultural learning theory and language acquisition. These can be fruitfully linked: “the very same conversations that provide the opportunity for the child to learn language also provide the opportunity to learn through language.” (Wells, 1999, p.51). Interaction in S & T education needs to be thought- and talk-provoking.

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Indispensable tool: active learning

Here we probe learning theories of science & technology education for the role they assign to dialogue. The kind of science and technology that children are to learn does not merely consist of a wide array of facts that can be transmitted to the children by a teacher or a textbook. The main objectives of S & T-education in primary school are (Van Graft & Kemmers 2007):

- children get familiar with the process of ‘doing science’
- children acquire knowledge: not mere facts, but concepts in their context
- children develop an inquisitive attitude

These aims can only be reached fully, if interaction plays a prominent role. This role is eminent for three reasons:

1. learning originates from language in dialogue
2. reasoning processes are acquired through dialogue
3. learning to engage in dialogue creates an open mind for new ideas

Each of these reasons is explained here.

1. **Learning originates from language in dialogue.** When learners are engaged in problem-solving activities with peers and teacher, they learn through language. The aims of S & T education are in accordance with the current view on learning as a socio-cultural process (Vygotsky, 1978; Leontiev, 1981). Learning is not a matter of transmission from an expert (teacher) to novices (the pupils), but consists essentially of transformation or co-construction by active learners (the pupils) with the support of a facilitator (teacher). In the social exchange children make meaning of the world surrounding them. In such transactions classroom discourse functions as a thinking device (Wertsch & Toma 1995). “...language is the essential condition of knowing, the process by which experience becomes knowledge” (Halliday 1993, p.94). In interaction children acquire new concepts and interconnect concepts. Moreover, it is oral interaction that permits them to function at their highest cognitive level. The abstractions needed to cope with written language restrict the level of cognitive operations a child can manage with as much as three years (Hammond 1990, cf Halliday 1993, p.110; Snow & Kurland 1996; Dickinson & Tabors, 2001)

2. **Reasoning processes are acquired through dialogue.** Learning through dialogue is expanded in approaches such as dialogic inquiry (Wells 1999), inquiry learning (van der Linden & Renshaw 2004; Flick & Lederman 2006), inquiry-based science education (Harlen & Allende 2009), and dialogic teaching (Alexander, 2004; Mercer & Littleton 2007). Dialogue is also part in the Dutch version of the content-based approach: ‘Taalgerecht vakonderwijs’ (Content based language education) (Hajer & Meestringa 2009). Through interaction children think things through, construct representations, and reflect on solutions and explanations. For instance, when making a prediction before executing an experiment “one is involved in a form of theorizing, as one examines one’s beliefs about the phenomenon in question and relates them to any other knowledge one has that is relevant to the possible outcomes of the experiment. As important as the actual predictions that students make, therefore, are the reasoning processes that
lead to them.” (Wells, 1999, 215; italics by authors). Thinking and exchange of thinking constitute integral elements of science activities. Children’s ‘small ideas of science’ gradually are linked together towards broader understandings, the ‘big ideas’ of science (see Harlen & Léna, chapter 1). It is this process that is brought about by interaction. The central task of science education is to scaffold student engagement in such discourse (Metz 2006).

(3) learning to engage in dialogue creates an open mind for new ideas. Inquisitiveness and wonderment lead to thinking and talking. So far, we viewed dialogue as a means to an end, i.e. the construction of knowledge. However, dialogue as an end-in-itself has been discussed recently as a broad educational aim - in the challenging form of a written dialogue (Wegerif et al. 2009): “to be more dialogic (...) is to be more open to other voices, more able to question and to listen and so more able to allow new unanticipated meanings to emerge” (op. cit. p.185). It is the creative space of dialogue (op. cit. 197) that is emphasized here.

Strategic purpose: language acquisition

Within the field of linguistics interaction is since long accepted as a major source for language acquisition (Gass & Mackey 2006), whether first language (since Bates 1976) or second (since Hatch 1978). Here we outline only the basic idea. Details concerning the required quality of interaction are the focus of the rest of this chapter. Learners need to receive comprehensible input that provides the model for the target language (Krashen 1980). Such input must be complemented by pushed, comprehensible output (Swain 1985, 1995, 2005). By speaking the learner goes from semantic processing merely focussed on comprehension to complete linguistic processing needed to construct new and accurate linguistic knowledge. In sum, learners must be challenged to produce language in order to learn (see overview in Damhuis 2008). Interaction brings about language proficiency in a broad sense, and in more specific sense communicative competence. Both are important objectives in language education.

This central role of interaction in language education can be used as a strategic purpose for S & T education. In the Dutch curriculum only a limited portion of time is allotted to S & T. Therefore alliance with other subjects is a good strategy to secure more learning time spent on S & T topics. Linking S & T topics with language education combines mutual objectives while each subjects maintains its own merits. Moreover, as reported earlier, dialogue can be seen as a broad educational aim for any subject. So, interlinking language education, S & T and other subjects has a great advantage.

HIGH QUALITY INTERACTION MADE CONCRETE

A considerable body of research is dedicated to identifying features of interaction that enhances linguistic and cognitive development (e.g. Halliday 1993; Wells 1999; Nystrand et al., 2003; Alexander, 2004; Mercer & Littleton, 2007; Schwarz et al. 2009). The educational context varies from language arts to history to science and

- “questions are structured so as to provoke thoughtful answers (...);
- answers provoke further questions and are seen as the building blocks of dialogue rather than its terminal point (Alexander, 2004 p.32).

Working with teachers made us aware of their need for even more concrete descriptions of what ‘exactly’ they could do in their everyday practice. Based on the arguments for interaction as an indispensable tool and a strategic purpose presented in earlier sections, we focus here on three characteristics that are vital specifically for S & T education:

(1) Rich content in combination with extensive output
(2) A coherent and productive line of enquiry
(3) Deepening feedback

Table 1. Features of high quality interaction that are essential for S & T education
(in brackets the reference to the item on the LIST Checklist, Damhuis, de Blauw & Brandenborg 2004, Damhuis & De Blauw 2008)

<table>
<thead>
<tr>
<th>Child</th>
<th>Teacher</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Rich content combined with extensive output</td>
<td></td>
</tr>
<tr>
<td>takes turns on his/her own and expands on his/her turns (3c)</td>
<td>refrains from asking questions continuously (3c)</td>
</tr>
<tr>
<td>answers at length in response to open questions (3d)</td>
<td>asks when necessary open and inviting questions (3d)</td>
</tr>
<tr>
<td>responds at length on his/her own to teacher's statement (3e)</td>
<td>makes a thought provoking statement occasionally (3e)</td>
</tr>
<tr>
<td>uses and expresses a higher level of thinking (complex cognitive language functions, such as comparing, reasoning, making conclusions) (4c)</td>
<td>encourages to use and verbalize a higher level of thinking (complex cognitive language functions, such as comparing, reasoning, making conclusions) (4c)</td>
</tr>
<tr>
<td>2. Coherent and productive line of enquiry</td>
<td></td>
</tr>
<tr>
<td>continues expressing and verbalizing communicative intentions (4a)</td>
<td>connects to the content of child’s conversation (contingent discourse) (4a)</td>
</tr>
<tr>
<td>expands on content (4d)</td>
<td>builds on the content of what the child says (4d)</td>
</tr>
<tr>
<td>uses my support to express his/her meaning (negotiation of meaning) (4b)</td>
<td>supports the child in clarifying his/her meaning (negotiation of meaning) (4b)</td>
</tr>
<tr>
<td>3. Deepening feedback</td>
<td></td>
</tr>
<tr>
<td>contributes in a well structured manner (5b)</td>
<td>structures the contribution of the child and summarizes when needed (5b)</td>
</tr>
<tr>
<td>accepts translation and makes use of it (at a later moment) (5c*)</td>
<td>translates the child’s contribution into more appropriate language and encourages the child to respond (re-voicing) (5c*)</td>
</tr>
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</table>
These characteristics were dissected into concrete child behaviour that shows opportunities for linguistic and cognitive development, and corresponding teacher strategies to foster such behaviour: table 1. Together with the more general characteristics of communication prerequisites and language input they form the LIST Checklist for talk- and thought-provoking interaction (Damhuis, de Blauw & Brandenborg 2004, Damhuis & de Blauw 2008). LIST is the acronym for Language acquisition through Interaction Strategies for Teachers. Thus, we identified concrete strategies a teacher could use in real life, presented and used within the framework of language- and thought-provoking interaction.

(1) Rich content in combination with extensive output. This combination is required for thought- and talk-provoking interaction, a refined construct of important aspects of exploratory talk (Mercer & Littleton 2007) and dialogic spells (Nystrand et al. 2003). Interaction only qualifies as thought- and language provoking if it contains features of extensive output and rich content in combination (De Blauw et al. 2010). Within the perspective of language and cognitive development form and function together determine the quality of a response.

Example 1: Teacher: How could they solve this problem? Child: They have to take out the dead fish, because they poison the water. This thought provoking question has an open form, allowing for an extensive answer, and thus is simultaneously talk-provoking.

Example 2: Teacher: What is poisoning the water? Child: The dead fish. Although still thought provoking, the question form is closed, allowing only a limited output: not talk-provoking.

(2) Coherent and productive line of enquiry. High quality interaction is not a series of autonomous question-answer exchanges. But answers are followed up by the teacher and used to build a coherent line of thinking and reasoning. This category builds on the concepts of exploratory talk (Mercer & Littleton 2007), coherent line of enquiry (Alexander 2004), ‘uptake’ (Nystrand et al 2003), and productive dialogue (Wegerif et al 2009).

(3) Deepening feedback. This encompasses feedback that leads to more in-depth thinking and talking. One of the actual strategies concerns structuring and summarizing children’s contributions. This makes the scientific process explicit, and draws attention to important content of children’s’ contributions to support acquisition of knowledge (objective 1 and 2 of S & T education). Moreover, it contributes to the coherence of the line of enquiry.

Revoicing. Children express new ideas, suggestions and reasoning often in everyday language, hesitatingly, in search for words, and support the conveyance of their intentions by gestures. For cognitive and linguistic development this is the optimal moment to revoice this contribution: in her feedback the teacher (a) values the contribution, (b) offers the proper wording in scientific and technical terms, and (c) invites the child to consider approval (O’Connor & Michaels 1993, 1996; Damhuis 2008).
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INTERACTION COMPONENT OF TEACHER PROFESSIONALIZATION IN S & T

How can we contribute to teacher professionalization in S & T education? In order to realise a rich learning environment for science and technology education, VTB-Pro builds her program for teacher professionalization on three pillars (Kuijpers & Walma van der Molen, 2007):

(1) knowledge of scientific and technological concepts and the skills necessary for the scientific thinking process,
(2) attitude towards science and technology,
(3) pedagogic-didactic skills, especially with respect to inquiry learning.

Obviously, the realisation of high quality interaction constitutes a major didactic skill (pillar 3), and hence has to be included in professionalization. In addition, thought- and talk-provoking interaction helps teachers in their own S & T development (pillar 1). It should be employed to make explicit the scientific thinking processes at their own cognitive level, feeding their insight in children’s thinking processes and how to foster those: positive impact on didactic skills (pillar 3). Also, when teachers themselves get involved in proper thought- and talk-provoking interaction, it fosters their own inquisitiveness, contributing to a positive attitude towards S & T (pillar 2). It may even help them to overcome their perceived inadequacies in S & T knowledge. Naturally, teachers need a basic knowledge to ensure rich content and the deepening of insights by pupils in the phenomena at hand (see pillar 1). But with the proper interaction skills in their repertoire, they are able to function as facilitator of the discovery process of their pupils and won’t feel uncomfortable when they admit not having all knowledge at hand. Their interaction skills relieve their anxiety about unpredictable pupil contributions to the creative dialogue. In sum, an important part of teachers’ professionalization in S & T education must consist of learning how to realise thought- and talk-provoking interaction.

IS HIGH QUALITY INTERACTION IN S & T EDUCATION LEARNABLE?

We argue that learning how to realise high quality interaction must be a part of teacher professionalization in S & T education. This only makes sense, if the way in which a teacher interacts with her students is viable to change. We show that teachers are actually capable of realising different types of interaction describing a training course we developed, and presenting findings concerning the efficacy of this course.

The core of the professional learning course we developed for (student) teachers in primary education (De Blauw & Damhuis 2006) is the classroom interaction checklist described previously. The course is especially structured in order to yield actual changes in classroom conversations. Major elements are: the use of video footage of teachers’ own classroom conversations, and team meetings combined with individually oriented teacher guidance in the classroom (Damhuis & De Blauw 2008). During the training, participants choose their own learning objectives from the checklist and practice these chosen strategies in their classroom.
interactions. Videotaped interaction in the participant’s own classroom forms the base for each coaching session with the participant.

This interaction course was experimentally integrated with enquiry learning in S & T (Van Graaf & Kemmers 2007) to develop a Language, Science & Technology teacher training.

From eight different schools in The Netherlands teachers and their pupils in Dutch grades 3 and 4 (age 6-8) participated. In the team meetings the teachers experienced S & T activities and learned about S & T education and the role of high quality interaction. Most importantly, they designed S & T activities for their classes and practiced their strategies for realising thought- and talk-provoking interaction. Two experimental themes were developed and conducted in the classroom. Simultaneously, the teachers practiced the learning objectives from the LIST Checklist, and were coached on these points.

Can this specialised approach be successful? First we present results of small-scale quantitative studies on learn ability of interaction strategies of the LIST Checklist. These studies use data from training courses where the link between language and thought was realised within a broad range of school subject areas, not specifically S & T. Next the focus is on S & T. A qualitative analysis of a lesson in the theme Sound is offered. This detailed analysis demonstrates how teachers may realise thought- and talk-provoking interaction in S & T education.

**SPEAKING TIME AND QUESTION BEHAVIOUR**

*To what extent are the concrete strategies from the LIST Checklist learnable in the real life practice of education?* Here we present findings on two aspects: general speaking opportunity for children, and question behaviour of teachers. Although we work with distinct, actual strategies, we do not consider them as ends-in-itself (a risk signalled by Mercer and Littleton, 2007, p.35), but within the framework of thought- and talk-provoking interaction (see earlier section).

*Research questions.* Innovations for early S & T education should start both at in-service level with teacher and at pre-service level with student-teachers. The first research question originates from the general aim of the training course: (1) Do (student) teachers create more speaking time for children after the course? Within this broad aim, participants choose their specific learning objectives. Two important strategies led to these specific research questions: (2) Do (student) teachers ask less questions after the course? (3) Do they pose relatively more open questions than closed questions after the course?

*Method.* Conversations between (student) teacher and pupils were videotaped before and after the course. A 10-minute episode of each video was analysed.

Speaking time for teacher and for children was measured in seconds, using a stopwatch while watching the video recording.
Questions were transcribed from the video-recording, and categorized for type with respect to the extent of appropriate answer. Besides open and closed questions (example 1 and 2 in earlier section) a what-action question was distinguished:

Example 3: Teacher: *What should we do now?* Child: *Close this pipe.* This type may create more opportunity for active participation than the closed question, but generally still less than the open question.

Inter-rater reliability established for three juries of two persons each reached an average Cohen's kappa of 0.86 (Damhuis et al. 2010).

We expected proportion of speaking time by the teacher, total number of questions by the teacher and proportion of closed questions by the teacher to decrease. An increase was expected for proportion of speaking time by the children and proportion of open questions by the teacher.

This study presents data from three teachers who participated in the LIST course as an in-service training and 8 student teachers following the course within the 4th year of the initial curriculum. They all had chosen one or both question strategies as learning objectives.

**Results.** All three teachers and five out of eight student teachers succeeded in providing children more speaking time after the training; figure 1. They reached a far better level than the 60% teacher proportion in traditional classroom discourse (e.g. Cazden 1988).

*Figure 1: Speaking time by Teachers (T) (white) or student Teachers (sT) (white) and children (grey) before the course (left column of pair) and after the course (right column of pair); (+ = expected direction of change).*

With respect to the total number of questions all three teachers changed towards the expected direction, but only three student teachers: figure 2. The expected relative increase of open questions was realised by two teachers and six student teachers: figure 3. The third teacher showed a decrease of open questions, but he already used the lowest total number of questions (figure 2).
Discussion and conclusion. Change is possible for (student) teachers, although not yet for all of them. The teachers actually changed their interaction in general as well as with respect to the chosen strategies of question use. Most student teachers improved with respect to type of question. Noteworthy is that these (student) teachers started out at quite different levels, but each was able to improve. The student teachers seem to have ignored the conditional part of the strategy of open questions: if necessary. This may require more emphasis during the course.

It requires further exploration of internal and external factors to explain differences and to find ways of optimizing the professionalization course. Future analysis will involve more participants in order to draw conclusions on the statistical significance of changes in the interaction. In addition, features of the quality of content will be investigated (see De Blauw et al. 2010).
PRACTICING HIGH QUALITY INTERACTION: A LESSON ON SOUND

What does high quality interaction in S & T education in primary schools actually look like? It is time to dive into reality.

Here we present Wendy and her class of 20 children aged 7-8 (Dutch grade 4) as a good practice example of what high quality interaction is about and how it looks like on a daily basis. Wendy participated in the collaborative project on developing interaction strategies in S & T education. Until this project Wendy, an experienced teacher, worked on S & T guided solely by a regular, frequently used Dutch textbook.

The class is involved in the theme ‘sound’. Normally Wendy follows Leefwereld (Lifeworld). As part of the special course on interaction and S & T education, she now has enriched the theme with thought- and talk-provoking dialogues. Today the children participate in a search for characteristics of ‘sound’. Sound is everywhere, you can hear it, see it and feel it. The teacher’s goal is to let the children discover aspects of the concept ‘sound’. We will focus on the specific role of interaction strategies used by the teacher, describing the lesson according to the steps of the so-called Inquiry Learning Cycle for S & T education developed by Van Graft & Kemmers (2007) and Kemmers et al. (2007).

Step 1: The problem

By way of orientation the children close their eyes for half a minute and have to describe what they hear. This prepares children for thinking about sound.

Would it be possible to hear nothing at all? This is the problem teacher Wendy brings into focus. The issue is explored jointly in a whole group conversation. Children put forward several suggestions for places where you hear nothing.

Teacher: On the planet Venus? Have you been there? Then how do you know?
Dennis: Because there are no people and all that. And also not wind.
Teacher: Is there no wind?
Dennis: I think (smiles)

Sounds are everywhere: on an uninhabited island, in an empty building, in a shed in the middle of a meadow. To reach complete silence a lot of things have to be not there. There are extremely few places where it is totally soundless, they conclude.

Strategies. What strategies does the teacher use? Teacher Wendy raises amazement and inquisitiveness. Nonverbally her face invites children to explain their ideas. The teacher keeps silent, gives listening responses, occasionally asks an open and inviting question, and makes use of summarizing to combine building blocks into the line of enquiry (Alexander 2004), thus deepening the content.

Coaching. What are important coaching objectives? In our in-service and pre-service courses for high quality interaction teachers learn that the-whole-group setting is not ideal for children to express ideas. A regular switch between whole-group and peer exchange in pairs is more effective in providing opportunities for children to produce extensive and rich output around a thought provoking issue. Wendy will try this later.
Step 2: Exploration

Now the theme is established, teacher Wendy introduces a second problem: *How does my sound come to you?* First responses are *with my ears* and because *you talk and then it goes a bit further*. Wendy follows up those ideas: *But how does that happen?*

Two children, Wesley and Mike, are each supplying pieces of the puzzle, at different moments in the line of enquiry. They are deeply thinking, as can be seen by their hesitating way of talking and the way they use gestures to convey their intentions. Teacher Wendy scaffolds how to put these pieces together, combining the building blocks offered by different children.

**Wesley:** That’s when you talk then eh there comes always, well look, for instance when I blow then it also comes further out of my mouth (hand indicates movement away from mouth). And when you talk then it is I think the same.

**Teacher:** That is has to do with air then?

**Wesley:** Yes, that it flies a bit further like that. All very quickly.

**Teacher:** Okay, so it has to do with air. (Then Diana contributes spontaneously, but on the earlier topic of 'where is no sound at all'. Teacher accepts and then allocates the turn to Mike)

**Teacher:** Mike, you want to say something on how sound comes to your ears?

**Mike:** Yes, I think it just goes to your ears (supports his words with a gesture) then to your brains and then your brains think "Oh somebody is talking to me, then I have to talk back".

**Teacher:** Okay. So the sound comes from my mouth and then what happens next Wesley? (combines now) The sound comes from my mouth (indicates movement with finger).

**Wesley:** and then uh (points)

**Teacher:** then you said it went through...?

**Wesley:** the air and then it comes slowly, then it goes very fast further to Mike.

**Teacher:** then it comes into Mike his...?

**Wesley:** his ear and that really goes so fast, you just can, yes, that is just, well that is awfully fast.

**Teacher:** Sound goes very fast. And Mike and then you say then it comes into my ear and then what is happening to it?

**Mike:** And then it goes very fast and then my brains think someone is talking to me and then I talk back.

**Teacher:** Okay. I think that’s a very clever idea.

**Strategies.** What are the strategies the teacher uses in the example above? The teacher offers ample opportunity for the children to contribute ideas. She encourages them to use complex cognitive language functions. She re-voices Wesley’s expressions into words belonging to science- and technology concepts: *it has to do with ‘air’* (O’Connor & Michaels 1996). By interlinking children’s ideas...
she builds up a coherent and productive line of enquiry (Alexander 2004, Wegerif et al. 2009). She designates the children’s answers as building blocks and involves the children themselves in actually performing the building. It is by the interaction strategies of the teacher in this classroom example, that the children are actively and jointly involved in expressing the reasoning process.

Coaching. On which points teacher coaching has to focus? There is a fine balance between providing opportunities to all children to actively participate and sticking to the conversation topic. The guideline we suggest for teachers is to focus on the line of enquiry and opportunities for building blocks, by taking up the contribution of a child in the ensuing turn (Nystrand et al. 2003).

Step 3: Setting up the experiment or plan

Next Wendy demonstrates two experiments. Experiment 1 makes use of a washtub with water on a table in the middle of the circle. The children are invited to predict what will happen when she would throw in two marbles. Sink is the first reaction. Wendy continues: And what else?

Theodore: Well for instance when you throw a very big stone in the water, then it goes into the water indeed but then also water comes out again. Because there is no air in that stone. And when, when throw in water for instance, then it just goes fuller.

Teacher: Then it gets fuller yes.

... (a bit further in the conversation) ...

Diana: Well, look, then you suddenly hear ‘ploomp’ and then it splashes a bit upwards.

Teacher: And then what is happening with the water?

Diana: Well, that moves very fiercely to and fro and all that.

Strategies. The teacher models hands on, minds on, talk it over. Prompting predictions is thought provoking (Wells 1999). Wendy creates the opportunity for active, extensive output. The children utilize the opportunity to put into words what they expect to happen. They use complex cognitive language functions such as reasoning, concluding, cause-and-effect. Thus, the teacher realises the combination of being thought and talk provoking that is required for high quality interaction. Some ideas already prelude on ‘waves’ and sound: this strand becomes more explicit in the next step.

Coaching. Special attention is needed for re-voicing, translating the child’s contribution into more scientific and technological terms, is difficult for teachers. In this classroom dialogue Wendy actually did not reply with extensive feedback to Theodore’s contribution, but she could have re-voiced as follows: Right, so the level of the water rises, because of the volume of the stone. That’s is good prediction. She then could have built on: And so, if we would drop in a very tiny stone, we would see nothing. Acting that way a teacher can deepen the child’s idea, and provoke talk as well as thought by using a thought provoking statement in stead of a question: rich content and extensive output.
Step 4: Conducting the experiment

After all these predictions it is time now to demonstrate what happens throwing the marbles into the water.

Teacher: 

"Manja you said it will make waves and that is also like what happens with sound. When I produce sound with my voice, then it goes a bit in waves through the air, then it reaches you (supports with hand-and arm gestures).

Next, the teacher performs another experiment, going through step 3 and 4 once more: children predict and observe. On the table there is another tub. This one is covered with plastic foil and some icing sugar. By beating a drum Wendy demonstrates that ‘by sound things can be moved’. One of the children adds that she sometimes feels her father’s drumming in her stomach.

Strategies. One of the strategies the teacher uses here is that she revoices the children’s observations into scientific language. She also explicitly draws a conclusion, taking up children’s contributions (Nystrom et al. 2003), modelling step 5 of the Inquiry Learning Cycle. Acting in this way the reasoning process becomes audible for everybody (Wells 1999).

Coaching. Coaching draws the teacher’s attention to the fact they have to assess which level of insight in the phenomena their pupils can handle. In this first orientation on the theme children get a bit closer to understanding ‘sound’, although not yet the full scientific picture of ‘sound makes particles move in waves’. Teachers search for a balance, and a gradual deepening of insight.

Step 5: Drawing conclusions

After these experiments Wendy draws a main conclusion about what they all have experienced now: sound is something one can hear, feel, and see. When children came up with a counter argument, the experiment was repeated and talked over until everything was clear.

Strategies. By using several interaction strategies the teacher has integrated high quality interaction in steps 3, 4 and 5. She discusses the observations and lets children reflect on how phenomena might be connected. So they are learning through language (Halliday 1993). Wendy also models how they can go about investigating their ideas. She creates a spontaneous bridge between children’s amazement and the process of doing science, objectives 1 and 3 of S & T education. With these child contributions and her own feedback she enables children to acquire knowledge of the features of ‘sound’, objective 2.

Step 4: Constructing an object and Step 5: Testing the object

The whole group activity has ended now. In couples the children go working on assignments that concern ‘sound’. In various ways children go through steps 3, 4 and 5 of the Inquiry Learning Cycle. For instance the hands-on activity of constructing a telephone from two plastic cups and some string.
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Strategies. What and how do the children learn? They discover while doing and discussing how things work and don’t work. The teacher frequently looks into their activities, having them express verbally what they see, predict, compare and are trying: the reasoning process (Wells 1999).

Coaching. Here coaching focuses on requirements of small-group work. It is essential in these assignments that children not just follow a step by step instruction. They need to consider several possibilities, reason about expected success, and share their ideas with others. This creates the opportunity for building up new ideas, understandings, concepts, even though they are still pre-concepts instead of full scientific concepts. In step 6 we will see that Mike has picked up the concept of ‘vibration’. The teacher is needed to deepen the exchanges. She may do this by following up (Alexander 2004, Nystrand et al. 2003) on what the children are saying and doing when she joins a pair or group. This is also her role when the pairs reconvene in the whole group.

Step 6: Presenting

After each couple of pupils has fabricated and tested their telephone, a whole group discussion follows. The children tell how things went and what they discovered. The teacher offers feedback. At the end of the presentations the teacher summarizes the findings.

Here we see how two children, Diana and Mike express their findings from their pair work.

Diana: Yeah look, when you talk through it just very softly you can still hear it quite well. And very softly from the big distance then you just cannot hear it (means ‘without the phone’).

Teacher: Okay.

Diana: And I also thought it very funny, for then we were going to construct it, but then we did not know that you had to hold taut the string, and then we went very loosely, Tonia stood eh like there and me here. And then I heard like: Tonia can you hear me. And then she couldn’t hear me every time and I also not. And then we went into the hallway and then we held it taut for we wanted to do it very far away, far from each other, and then we did hear it. And it did not matter whether there was a knot in, or not.

Mike: Well, I think that when you talk through the cup (accompanies his words with gestures and sounds). Look, I think it goes zoof zoof, the sound goes through the little hole, that air. Then the vibration goes there through the wire, swoosh, and then it arrives at the other cup.

Teacher: Okay, so your sound, what you say, goes through that wire to the other side, into the ear.

Mike: Yes.

Teacher: You have discovered many things. (Then addressing the whole group) What do you think I mean. What have they discovered?
Children repeat the discoveries, using their own words. Wesley repeats, Diana adds to it. The teacher emphasizes the important elements.

*Strategies.* What strategies are central here? Wendy creates great opportunities for the children to express verbally their process of discovery. She requests clarification when the verbalization is not completely comprehensible or not specific enough. So she elicits pushed output (Swain 2005). Together they will negotiate meaning. Wendy’s feedback is focused on S & T content, and more specifically on the thinking processes (Wells 1999). She draws the attention of the speaking child and all peers to justified conclusions that bear on the scientific content.

**Step 7: Deepening and broadening**

In the discussion of the results of their telephone-construction and testing, it is Theodore who presents a counter-experience. He himself could not hear Mike that well. He suggests an explanation. Wendy replies by advising him to study this more thoroughly.

Theodore: *Well, I discovered that I could not hear Mike so clearly. For with Mike there (stammers) was, were, look (rises and walks towards Mike’s cup on the other table), very many holes in there.*

Teacher: *Okay, that might have to do with it, yes.*

Theodore: *Then the air escapes from it!*

Teacher: *To investigate it again, to investigate whether it makes a difference, you should construct a new one and then you should use each of them. Hey, do I hear it better now with the cup with the hole or do I hear it better with the cup without the hole in it? You can investigate that.*

Theodore: *(nods)*

*Strategies.* The teacher uses an important strategy: she takes up Theodore’s contribution (Nystrand et al. 2003) and uses it to stimulate further research on the telephone. She models possible research questions. In addition, with this step the teacher will ensure to repeat and focus on all things the children have done, have seen, and have concluded. She structures, summarizes and re-voices in appropriate language, providing correct content in her feedback.

*Coaching.* Coaching should concern several ways of deepening and broadening. It may be difficult for teachers to extend the findings to new situations. An example in this theme could be the step to cell phones. This interlinks the concepts of sound as ‘waves through a wire’ and ‘sound as waves through the air’.

**High quality interaction in S & T education: conclusions**

The example of the classroom interaction of Wendy and her pupils demonstrates how it is possible to integrate high quality interaction into S & T education with 7-8 year old children. This ensures that the main objectives of S & T education in Dutch primary school as quoted earlier (Van Graft & Kemmers, 2007) are met.
DAMHUIS AND DE BLAUW

Wendy teaches according to the Inquiry Learning Cycle for S & T education enriched with high quality interaction. In this way she shows that:

- her children get familiar with the process of 'doing science' by exploring issues about sound, discussing problems with sound and solutions, and constructing telephones.
- they acquire knowledge: not mere facts, but concepts in their context: in this lesson they are beginning to form concepts of sound, waves, air, vibration.
- they develop an inquisitive attitude: children contribute ideas moving from own experiences with sound to wondering about the phenomenon itself; they use complex cognitive language functions, such as reasoning, cause-effect and conditions; children themselves are building up the line of enquiry and are actively and jointly involved in expressing the reasoning process.

That children are involved in such a language- and thought provoking way of learning is possible because their teacher demonstrates the features of high quality interaction as shown in Table 1. (1) she offers a rich content combined with extensive output, (2) she offers a coherent and productive line of enquiry, and (3) she offers deepening feedback.

Teachers and student teachers can acquire these classroom interaction competencies by courses especially focused on high quality interaction in S & T lessons.

CONCLUSIONS

In this chapter we have demonstrated that high quality interaction is vital for S & T education. So we propose an extended adagio for S & T education: hands on, minds on, talk it over. High quality interaction is thought- as well as talk-provoking. The characteristics are (1) extensive output in combination with rich content, (2) coherent and productive lines of enquiry and (3) deepening feedback. To become applicable in everyday practice by teachers, these characteristics are made feasible and workable in the form of the desired child behaviour and complementing teacher strategies.

We found that teachers and student teachers are indeed capable of incorporating high quality interaction in their S & T lessons, when they participate in specially designed courses. Therefore, in order to realise the objectives of S & T education, courses like this must be included in pre-service and in-service professionalization of teachers in primary education. One must bear in mind here, that a single workshop or lecture does not suffice. To acquire strategies for high quality interaction teachers as well as student teachers must participate in team meetings, practice in their own classes over a longer period of time and be coached during their practice. Investing in primary school teachers this way is a prerequisite and a guarantee for successful early S & T education.
NOTES

1 For general aspects of learning theory and S & T, other chapters in this volume offer more comprehensive discussions.

2 In the LIST Checklist the characteristics are arranged in five main categories: prerequisites, language input, active participation, quality of the content, and feedback.

3 This design research was conducted by Resi Damhuis & Akke de Blauw for the National Centre of Language Education (Nijmegen), and Marja van Graafland, Pierre Kemmers and Tjalling Brouwer for the SLO, the Netherlands institute for curriculum development (Enschede).

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Scope
Technology Education has gone through a lot of changes in the past decades. It has developed from a craft oriented school subject to a learning area in which the meaning of technology as an important part of our contemporary culture is explored, both by the learning of theoretical concepts and through practical activities. This development has been accompanied by educational research. The output of research studies is published mostly as articles in scholarly Technology Education and Science Education journals. There is a need, however, for more than that. The field still lacks an international book series that is entirely dedicated to Technology Education. The International Technology Education Studies aim at providing the opportunity to publish more extensive texts than in journal articles, or to publish coherent collections of articles/chapters that focus on a certain theme. In this book series monographs and edited volumes will be published. The books will be peer reviewed in order to assure the quality of the texts.