IMPLEMENTATION OF OBJECTIVES FOR LABORATORY WORK IN SECONDARY SCHOOL SCIENCE

The purpose of this case study of three laboratory exercises in biology, chemistry and physics is to show how three Swedish secondary school science teachers’ objectives for labwork are carried out in practice. What objectives do the teachers put forward for specific laboratory exercises, what objectives appear in supporting laboratory manuals and how do objectives appear in teacher and student interactions during laboratory work? In three cases, pre-interviews with teachers about their objectives took place, laboratory manuals were collected, video recordings of the actual laboratory exercises were made and post-interviews with teachers about these video-recordings took place. Comparisons between objectives expressed by the teachers, identified in laboratory manuals and identified in teacher actions and teacher-student interactions were made to examine how objectives appeared during labwork. The results show that the introduction of the laboratory exercise and its laboratory manual is very important for the way labwork is performed. In order for teachers’ objectives to be implemented, results in this study put forward that a correlation between objectives, laboratory manual and actual labwork is favourable. Objectives need to be explicit to the teacher and that teachers’ awareness of the need to pursue objectives is crucial.

Per Högström, Department of Mathematics Technology and Science Education*
Christina Ottander, Department of Mathematics Technology and Science Education*
Sylvia Benckert, Department of Physics*
* Umeå University, Sweden

Background

Laboratory work is considered important for student achievements in science education (Hodson, 2001). However, the pedagogic value of laboratory work has also been questioned (Hodson, 1990; Tobin, 1990). Many different objectives can be addressed in laboratory exercises. A European research study investigated teachers’ objectives for labwork in upper secondary school and at the first years of university studies (Welzel et al., 1998). Objectives described as important were: to link theory to practice, to learn experimental skills and to get to know the methods of scientific thinking (ibid). Objectives for laboratory work could also be related to students understanding and conceptual development, as well as to motivation, interest and practical skills (Högström et al., 2006; Wellington, 2000). Laboratory manuals are used by teachers to help students perform specific tasks in an established tradition of student labwork in school science (Lunetta, 1998). However, not much is known about the level of agreement between the teachers’ objectives and the manuals. Swedish secondary school teachers put forward objectives with cognitive aspects when talking about labwork in general. On the other hand, in the teachers’ objectives for specific laboratory exercises affective aspects significantly increased. Thus, teachers’ objectives were expressed differently in different contexts (Högström et al., 2006).

1 For a convenient terminology in this study, we have adopted from Welzel et al. (1998) objectives, which could include both wider purposes as well as aims designed in regard to a specific laboratory exercise.
Implementation of teachers’ objectives for laboratory work can be problematic due to, for example, practical constraints such as lack of time or resources and the way learning objectives are made visible to students in the laboratory context. Different approaches to realise intended objectives for labwork have been suggested and in such attempts, Berry et al. (1999) reported that secondary school students’ awareness of laboratory aims and purposes was a key factor in helping students to mentally engage with a laboratory task.

The study reported in this paper examined what objectives teachers put forward for a specific laboratory exercise and how these objectives actually were carried out in practice. The following questions were considered:

- What were the teacher’s objectives for the specific laboratory exercise and what objectives were put forward in laboratory manuals?
- What objectives appeared when the teacher introduced the exercise to students and when teacher and students interacted during labwork?
- In what way did teachers’ expressed objectives correspond to objectives appearing in teacher and student interactions?

**Method and Analysis**

The study was carried out as three case studies of three different laboratory exercises in Swedish secondary school: one in biology, one in chemistry and one in physics. In a Swedish secondary school context, teachers’ usually teach all science disciplines. The goals in the Swedish national syllabuses for the compulsory school are rather general and give teachers opportunities to interpret and decide “how and when” described objectives could be implemented (NAE, 2001). This instrumental case study (cf. Stake, 1995) intended to learn which of the objectives, given by the teacher beforehand, were actually seen in teacher and student interaction during the laboratory exercise. Empirical data consisted of pre-interviews with each teacher, manuals (i.e. instructions to students about how to perform the specific laboratory exercise), video recordings from the specific laboratory exercise and post-interviews with two teachers (one post-interview could not be performed).

Selection of cases was made from an original participant request to 55 science teachers from 11 secondary schools. Laboratory work had to be part of the teacher’s science teaching, chosen by the teacher and limited to single lesson activities. This means a laboratory exercise in a setting usual to the teacher. The three participating teachers from three different schools had time to do interviews about their objectives for laboratory work and they admitted video recordings as well as did their students. An overview of the cases is presented in table 1.

In a pre-interview, the teachers were asked to express their objectives for the specific laboratory task and to motivate those. Laboratory manuals were collected and analysis of the manuals was derived from a classification model where students learning outcome were specified in objectives for contents and processes (Ottander & Grelsson, 2006). For example, objectives for content could be identified in descriptions written to help students learn a theory or a model, to identify a phenomena, etc. Objectives for processes in a laboratory manual could be identified in descriptions designed to help students learn how to perform a specific procedure, to use equipment etc.
The lessons were video recorded, content logged, with set-up and interaction analysis inspired by Jordan and Henderson (1995). During the lessons digital video cameras (DVC) on tripods were set up in different positions to ensure that most of the classroom was covered. Also, a remote microphone was attached to the teachers. Complementary content logs were made while observing and recording and used together with video recordings, including transcripts, to identify interactive episodes during the lessons. In the video recorded data for each lesson, the teacher’s introduction to the laboratory task and his/her interactions with students were defined as interactive episodes. The objectives in the interactive episodes were analyzed by teachers’ explicit utterances, and as implicit invitations or requests in teacher and student talk and teacher actions. In the following excerpt, the objective to identify specified internal organs appeared:

You might need to open that one. Have you tried it? ((Uttered while picking up the voice box)) (Sofie, Case 1, encouraging one student group to search for the vocal cords).

Interactive episodes from the video recordings were used in post interviews with the physics and chemistry teachers. In researcher and teacher discussions, the teacher was given opportunities to stop at any time and to comment talk, interaction and action in each episode. Teacher comments were useful to further inform assertions made from analysis of video recordings.

Table 1. An overview of assignments and participants for included cases. All names are pseudonyms. * These internal organs are further referred to as ‘the package’.

<table>
<thead>
<tr>
<th>Science discipline (case #)</th>
<th>Teacher (years of teaching experience)</th>
<th>Students grade (# of students)</th>
<th>Specific laboratory exercise</th>
<th>Lesson time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology (1)</td>
<td>Sofie (4)</td>
<td>7th (11)</td>
<td>Dissection of a pig’s heart, respiratory organs, and kidneys*</td>
<td>45</td>
</tr>
<tr>
<td>Chemistry (2)</td>
<td>Lisa (25)</td>
<td>8th (14)</td>
<td>Examination of why polyvinyl alcohol (PVA) is a different plastic</td>
<td>60</td>
</tr>
<tr>
<td>Physics (3)</td>
<td>Vince (6)</td>
<td>7th (13)</td>
<td>Measurements of forces on a balanced lever and calculations of torque</td>
<td>50</td>
</tr>
</tbody>
</table>

Results

This study shows that the objectives expressed by the teachers before the lessons are implemented to different degrees in laboratory settings. As an example of the specific nature of analysis and findings from the cases, the laboratory exercise in biology is presented. Additionally, a summary of findings from the laboratory exercise in chemistry (Case 2) as well as in physics (Case 3) is presented.

Analysis of Objectives in Case 1: The Laboratory Exercise in Biology

The teacher Sophie expressed objectives concerning subject content knowledge (d-f, table 2) and handling of biological material (a-c, table 2) for the dissection task in the pre-interview (see table 2). Student instructions, i.e. the laboratory manual, were presented on five boards throughout the room. This presentation included key procedures, key questions and/or supportive words. Three objectives concerning subject content knowledge and procedural knowledge were identified (d, f and g, table 2). Analysis of objectives in lesson interactions specifically included the teacher’s introduction to the laboratory task. Sophie’s brief introduction was as follows:
Can everyone be silent? I have written on these boards and I want you to proceed in this order. (Points to the boards) It depends on different reasons. For example, if you start to make an incision in the package too soon you may puncture the lungs and they cannot be inflated. Begin with this one. I will take out your package and then you can begin. Try to identify the different parts. Gullet, windpipe, voice box, and so on.

In the introduction, two clearly stated objectives could be identified (d and g, table 2). Sophie wanted students to use and follow the manual in the specified order and she also wanted them “to identify the different parts”. These objectives were explicit in teacher utterances, and implicitly reinforced by talk and actions. For example, she directed students’ attention to the manual and gave them a reason why a specific order was necessary. Analyses of all interactive episodes show that all objectives identified in the interview were discussed with the students (table 2).

Table 2. Identified objectives in case 1: The laboratory exercise in biology. Objectives are arranged in the order they appear the first time and X indicates where objectives are identified.

<table>
<thead>
<tr>
<th>Identified objectives</th>
<th>Pre-interview</th>
<th>Laboratory manual</th>
<th>Lesson, introduction to task</th>
<th>Lesson, interactive episodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) to gain experience with several senses</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>b) to be acquainted with real biological material</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>c) to dare handle the package</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) to identify specified internal organs</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>e) to help students develop understandings about functions of organs</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f) to recognise similarities to human organs</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g) to perform specific procedures</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>h) to use and follow the manual</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

For this laboratory exercise in biology, objectives expressed beforehand correlated well with the written manual and actual labwork. There was a strong relationship in pre-interview, laboratory manual and lesson for the objective to identify organs (d, Table 2). Some factors seemed to be influential. Either if Sophie or any student initiated interactive episodes, she continuously and repeatedly put forward the objectives to identify specified internal organs and to help students develop understandings about their functions (d and e, Table 2). In regards to the package, Sophie’s talk and actions implicitly put forward the objectives to gain experience with several senses, to be acquainted with real biological material and to dare handle the package (a, b and c, table 2). The laboratory manual presented what students were supposed to recognise as important, with necessary content correlated to the teacher’s objectives. They were used as a resource for both teacher and students during labwork. For example, when students wanted to discuss a specific finding, they could use wording from the manual to explain what procedure that showed their finding. Multiple evidence of the teacher’s expressed objectives appeared throughout the entire lesson, therefore we could assert that Sophie was well aware of what objectives she wanted to pursue during labwork.

Analysis of Objectives in Case 2 and Case 3: Summary of Findings

In case 2 the teacher Lisa expressed in the pre-interview eight objectives for the laboratory exercise in chemistry. The teacher’s main objectives were: to recognise “equal solves equal”, a widespread rule of thumb used in Sweden that refers to the concept of solubility; to discover
relations between PVA and this rule of thumb by repeated procedures. During the lesson most objectives seemed to be overshadowed by two other objectives: to use and follow the manual; to write a report. Students’ actions and talk showed how they emphasized explicit problems related to the manual and the report. To be able to make a full report, the students had to follow the manual. However, during the lesson, Lisa tried implicitly to make students figure out that the rule of thumb was involved in their labwork. This could be illustrated with a comment by Lisa, addressing one of the student groups, “Maybe there are differences between water and wipe-washer fluid and acetone. Water and acetone are not chemically equivalent.”

The teacher’s objectives identified in the pre-interview encompassed more than what was actually put forward in the manual and the lesson. Analysis indicated that the intended content knowledge in this case, such as properties of PVA and its associations with every day life, might have been too extensive for the students to grasp. Most of the teacher’s objectives were not made explicit to students during initial lecturing or during labwork and the laboratory manual did not correspond well to objectives put forward beforehand.

In case 3, the laboratory exercise in physics, the teacher Vince expressed six objectives in the pre-interview and four objectives were put forward in the laboratory manual. This manual was not adapted to students’ prior knowledge and the problems that thus occurred reduced the teacher’s possibilities of implementing his objectives. In the introduction, Vince referred to students’ textbooks, and explicitly expressed that the manual had to be read and used. Vince also demonstrated how students could assemble the equipment and showed how to balance levers, one of the important procedures included in conducting measurements as described in the manual.

During labwork, Vince’s support to students was very intensive. However, as students had difficulties in reading and following the manual, the teacher mainly had to support and guide students through it. The laboratory manual was accordingly of great importance. The manual showed what procedures to perform but to learn these procedures seemed to be problematic during students’ labwork. Students focused on the ideas of what to do, like a recipe, rather than thinking about the ideas that they were exploring. Time didn’t seem to be enough to help them develop their own thinking, to encourage their problem solving and their cooperation, a problem put forward during the post-interview. The teacher’s talk and actions showed how easily one objective became dominant even though more objectives were put forward beforehand.

Conclusions and Implications

Results from this study show that it is important that the teacher have a clear view of what to pursue during labwork and that the manual cohere with this view. Each teacher’s awareness of which (or how many) objectives to pursue showed to be of great importance. Without pinpointing what amount is most favourable, results imply that too many objectives could be problematic. When teachers’ interventions during labwork correlated to objectives put forward beforehand and in manuals, it seemed to favour implementation of objectives and opportunities to make laboratory exercises run smoothly. Another indication was that student knowledge of the content being explored also could be of importance. Efforts made before the laboratory task to make explicit the objectives might improve the possibilities for implementation. However, in neither of the presented cases this was done.
Teacher and student interaction provides opportunities to repeat and clarify objectives in relation to students’ talk and actions, where awareness and a keen way of behaving could promote implementation. The teacher in case 1 had a clear view, which also was reflected in interactions with students during labwork, where the teacher showed awareness of the importance of students making their own reflections and continuously and repeatedly put forward objectives students’ should recognize. In case 2 also, the objectives were clear to the teacher. However, during labwork she held on to the view that students should discover the rule of thumb, and interactions with students did not change this view. Most objectives remained undiscovered by students. Case 3 showed inconsistency between the teacher’s objectives and the ones put forward in the manual, hence indicating an uncertainty of what to pursue. During labwork, intensive interaction with students made objectives put forward beforehand diminish in favour for problems emerging from the use of the manual.

The laboratory manual was used in most interactions in all three cases. In the case of laboratory work in biology (case 1), objectives in the manual cohered well with the teacher’s main objectives. The other two cases did not show similar coherence. Results suggest that laboratory manuals need to put forward objectives consistent with the teacher’s objectives and the labwork context. It is also important that the level of the manuals is appropriate to students’ prior knowledge.

Results suggest that the teacher need to make objectives explicit to students and the same objectives are preferably repeated, and thereby not taken for granted, in the introduction to the task and in teacher and student interaction during labwork. Connections between what teachers’ want to do, what they say they do and what they take for granted have impact on how students perform their task (cf. Fourez, 1997; Roth, 2006). Results from this study could be valuable for teachers who aim to facilitate the implementation of objectives for labwork in secondary school and will be discussed in the presentation.

References


