# INQUIRY-BASED SCIENCE EDUCATION AND SPECIAL NEEDS – TEACHERS' REFLECTIONS ON AN INCLUSIVE SETTING

**Simone Abels**
simone.abels@univie.ac.at | Universität Wien, Austria

**ABSTRACT**

Many countries in the world signed and ratified the UN Convention on the Rights of Persons with Disabilities (2006) in order to ensure inclusive education at all levels. Nevertheless, dealing with differences in the classroom is seen as one of the biggest challenges teachers – also science teachers – face at the moment. Additionally, there is a lack of research in science education how to foster students appropriately in regard to their diverse pre-conditions. Research studies often recommend carefully scaffolded inquiry-based teaching approaches. This article is divided in two parts. The first part attempts to sum up what is known about the inclusion of students with special needs in science classes teaching them inquiry-based. The second part introduces a case study which investigates an open inquiry-based learning environment in an inclusive middle school. The learning environment is videotaped and reflected with the teachers. Ideas for change are developed. Conclusions are drawn for the facilitated competence gain for students with and without special needs.

**KEY WORDS**

Special education; Inquiry-based learning; Inclusion; Reflection; Case study.

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# Inquiry-Based Science Education and Special Needs – Teachers' Reflections on an Inclusive Setting

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## INTRODUCTION

Inclusion has its origin in special needs education (UNESCO, 2005). In 1994 the UNESCO *Salamanca Statement and Framework for Action in Special Needs Education* claimed that «those with special educational needs must have access to regular schools which should accommodate them within a child-centered pedagogy capable of meeting [their] needs» (United Nations & Ministry of Education and Science Spain, 1994, p. viii). In recent years the majority of the countries in the world have signed the UN *Convention on the Rights of Persons with Disabilities*[1], which means those countries have to take the responsibility to implement an inclusive school system. The right to education for every student was already set in 1948 (United Nations, 1948). In the meantime, the UN added that education «on the basis of equal opportunity» cannot be denied (United Nations, 2006, p. 16). Equal opportunity means «genuine access to learning experiences that respect individual differences and quality education for all focused upon personal strengths rather than weaknesses» (Meijer, 2010, para. 2). Accordingly, inclusion is defined as

1 http://www.un.org/disabilities/countries.asp?id=166 (Retrieved October 21, 2013).

> a **process** of addressing and responding to the diversity of needs of all learners through increasing participation in learning, cultures and communities, and reducing exclusion within and from education. It involves changes and modifications in content, approaches, structures and strategies, with a common vision which covers all children of the appropriate age range and a conviction that it is the responsibility of the regular system to educate all children (UNESCO, 2005, p. 13, original emph.).

Important is, for one thing, the idea of differentiation addressed in this definition as a strategy to provide equal opportunities. And for another thing, the attitude is crucial that the education system has to be made inclusive, not the student has to be made includable.

The perspective is that every student should be perceived as having particular learning needs. Furthermore, in many mainstream schools social developments like globalization, migration, demographic and value change are notable, increasing the diversity of students attending the same school (Krell, Riedmüller, Sieben & Vinz, 2007). Thus, all teachers should develop competencies such as individualizing, differentiating and diagnosing to meet the individual needs of all students coming together in one classroom at least partly to be supported by special educators. Education policy and teacher education have to shoulder responsibility to support teachers regarding these demands.

Empirical evidence for the normative demands is coming from the OECD. PISA has revealed that countries with inclusive school systems are more likely to be high-performance countries (OECD, 2010). One indicator for an inclusive system named by the OECD is that students are rarely transferred out of school because of special educational needs.

Despite the ratification of the policy documents and this data, inclusive education is not facilitated for every student yet, especially in those countries which traditionally pursue a segregated school system (Sliwka, 2010). For example, in Austria about 41% and in Germany almost 79% of the students with special educational needs are taught in separated settings (European Agency for Development in Special Needs Education, 2007, 2012).

This issue has not only to be discussed systemically on a macro level, but also on a micro level concerning equal learning opportunities in the classroom which are not sufficiently provided. «A resistance from practitioners to change and develop their professional practice to meet the demands and challenges of inclusive education, have led to extremely variable and often poor practice in the area» (Lloyd, 2002, p. 111). Teachers view the differences of their students as one of the biggest challenges to deal with in the classroom (Meijer, 2010). Nevertheless, it is an educational demand and political obligation to adapt teaching practices to the specific needs of all students in a mainstream school, including students with special needs. Research has to provide evidence-based implications for teachers how different students can be fostered best in one classroom.

At the same time as the inclusion movement proceeded, the «Science for All» movement was sharpened (National Research Council, 1996). School science still has the purpose to prepare students for future studies and careers in science, but this is not the only obligation anymore. «[T]he primary and explicit aim of the 5-16 science curriculum should be to provide a course which can enhance 'scientific literacy', as this is necessary for all young people growing up in our society, whatever their career aspirations or aptitudes» (Millar & Osborne, 1998, p. 9). According to the OECD (2006) scientific literacy refers to an individual's:

- Scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues
- Understanding of the characteristic features of science as a form of human knowledge and enquiry
- Awareness of how science and technology shape our material, intellectual, and cultural environments
- Willingness to engage in science-related issues and with the ideas of science, as a reflective citizen (OECD, 2006, p. 23).

Life-long learning and acting responsibly in a democratic society are crucial in our rapidly changing, technology-driven culture. Therefore, students need to develop the capacities «to apply knowledge and skills in key subject areas [like science] and to analyse, reason and communicate effectively as they pose, interpret and solve problems in a variety of situations» (OECD, 2010, p. 17). Methodologically and on a more practical level, inquiry-based science education (IBSE) is rated as an appropriate approach so that students can develop these capacities in science and become scientifically literate (European Commission, 2007; National Research Council, 2000).

Inquiry «refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world» (National Research Council, 2000, p. 23). Teaching inquiry-based strives for three aims:

- to construct scientific knowledge,
- to learn how to perform an investigation and
- to learn about inquiry (Abrams, Southerland & Evans, 2008).

Just like dealing with differences, teachers also struggle with the implementation of IBSE into their science teaching practice and express a lack of training in this field (Barron, Finlayson & McLoughlon, 2012; Roehrig & Luft, 2004). Teaching inquiry in a highly diverse classroom could be considered as the major challenge. The daily practice of science teachers has to be empowered for change in terms of the inclusive demands posed by education policy (cp. Lloyd, 2010). Science educators seem to be ill-equipped to teach students with disabilities while special educators are rarely trained to teach science. In addition, the important collaboration between the two professions appears as neglected (Villanueva, Taylor, Therrien & Hand, 2012).

Many general education teachers and science education researchers doubt that the performance of special needs students is sufficient to fulfil the sophisticated demands of science instruction, e.g., high level thinking, problem solving and inquiry learning (Ellis, 1993; Steele, 2004; Sullivan Palincsar, Magnusson, Collins & Cutter, 2001; Woodward & Carnine, 1988). «From studies of traditional (i.e., no inquiry, text-based) science instruction – for example, Carlisle and Chang's (1996) three-year longitudinal study of students with learning disabilities – we know that special needs students fare poorly and express doubts about their capacity to perform successfully in these classes« (Sullivan Palincsar et al., 2001, p. 16). Finkel, Greene, and Rios (2008) ENREF 6 raise concern that inquiry-based learning should not be considered as a panacea for supporting diverse students in becoming scientifically literate.

However, taking the requirement «Science for All» seriously, science education for students with special needs has to provide equal learning opportunities. Allowing for students with disabilities in the «development of classroom lessons ultimately makes the science class more inclusive. Moreover, it ensures that all students learn about science and become scientifically literate, which is a stated goal in the National Science Education Standards (NRC 1996)» (Trundle, 2008, p. 80). In addition to this normative statement, the limited number of empirical studies gives evidence positive for the inclusion of special needs students in carefully scaffolded inquiry-based science instruction.

## PURPOSE AND LIMITATIONS OF THIS ARTICLE

On the basis of recent studies in the fields of science education and special education this article will show that IBSE can be an appropriate approach in inclusive settings when it is carefully scaffolded. Evidence-based practices how to scaffold an inclusive class will be introduced. Most of the research results arise from control group design studies. The case study presented here tries to give an in-depth look how two teachers deal with students learning inquiry-based in an inclusive setting. The teachers' aims and priorities, but also their difficulties and conflicts will be worked out. The first reflective meeting with the teachers will be presented here where the teachers developed solution approaches together with the researcher.

The case is an urban lower secondary inclusive middle school. The article here focuses on an eighth grade class passing through a three day open inquiry process. Five of the 20 students are officially diagnosed as having special needs.

Special educational needs are diagnosed in different areas and support is provided accordingly in form of extra resources. Key-areas are:

- learning capacity and behaviour, especially scholastic learning and the ability to cope with disability in the learning process;
- speech, speaking, the communicative act, handling speech problems;
- emotional and social development, experience and self-control, dealing with disturbances, inexperience and behaviour;
- intellectual development, handling intellectual retardation;
- physical and motor development, dealing with severe disabilities in movement and with physical handicap;
- hearing, auditory perception, the ability to handle a hearing impairment;
- vision, eyesight, visual perception, the ability to deal with a vision impairment;
- state of health and state of mind, the ability to cope with a long-term illness (European Agency for Development in Special Needs Education, 2010, para. 14).

The first four areas and the last one listed are present at the school being in the focus here. Because of the special needs areas present in the class chosen for this case study and not least because of the expertise of the author the article at hand focuses on students with the focal areas of support «learning» as well as «emotional and social development», in other words on students with cognitive and emotional/behaviour disorders. Students with these needs form one of the biggest groups of the special needs population who are included in mainstream schools the most compared to learners with other special needs (Mand, 2009; Villanueva et al., 2012). The inclusion of students who need support in emotional and social development is seen as the most challenging though (Meijer, 2010). There are almost no studies about teaching students with severe disabilities inquiry-based (Courtade, Browder, Spooner & DiBiase, 2010).

Implications will be drawn for the implementation of IBSE in an inclusive setting. In addition, the in-depth results can enhance discussions among general and special educators.

As the research project is in the starting phase, only preliminary results can be reported that have to be analysed more systematically in the future. Contrasting cases have to be found to scrutinise the results like it is conventional in a grounded theory approach (Charmaz, 2012; Corbin & Strauss, 1990). Nevertheless, the detailed insight that is possible through this project provides relevant hints for educators and researchers concerning IBSE and inclusion.

## INQUIRY-BASED SCIENCE EDUCATION FOR STUDENTS WITH SPECIAL NEEDS

Students with a focal point of support in learning and/or social and emotional development face several challenges in the science classroom. For example, science textbooks «are often written 2 or 3 years above the actual reading levels of students with disabilities« (Steele, 2004, p. 20). Science vocabulary can be hard to understand and to use. Class discussions or lectures can be difficult to follow and the presented information hard to reproduce. Mnemonic strategies have to be developed with the students. Attention and concentration can be fast overburdened. The students can also be challenged to organize their notes or materials, e.g., while planning or conducting an experiment. Students with cognitive disorders often perform better in specific tasks than in situations where generalisation and transfer are needed (Steele, 2004). Scruggs and Mastropieri (2007) found that the psychometric IQ was a strong predictor for drawing inductive conclusions. Additionally, «negative attitudes can also create difficulties for students with special needs. Because of their cycle of frustration and failure, they may have trouble staying motivated and focused on a task» (Steele, 2004, p. 20). This can have effects on them establishing reliable relationships. Social skills are a developmental area which can affect group work (Steele, 2004).

These deficits are the reasons why students with special needs are often regarded as incapable of doing inquiry. This is understandable reading the list of abilities the National Research Council claims as necessary to do inquiry (table 1).

| Grades K-4 | Grades 5-8 | Grades 9-12 |
| --- | --- | --- |
| Ask a question about objects, organisms, and events in the environment. | Identify questions that can be answered through scientific investigations. | Identify questions and concepts that guide scientific investigations. |
| Plan and conduct a simple investigation. | Design and conduct a scientific investigation. | Design and conduct scientific investigations. |
| Employ simple equipment and tools to gather data and extend the senses. | Use appropriate tools and techniques to gather, analyze, and interpret data. | Use technology and mathematics to improve investigations and communications. |
| Use data to construct a reasonable explanation. | Develop descriptions, explanations, predictions, and models using evidence. | Formulate and revise scientific explanations and models using logic and evidence. |
| Communicate investigations and explanations. | Think critically and logically to make the relationships between evidence and explanations. | Recognize and analyze alternative explanations and models. |
| | Recognize and analyze alternative explanations and predictions. | Communicate and defend a scientific argument. |
| | Communicate scientific procedures and explanations. | |
| | Use mathematics in all aspects of scientific inquiry. | |

TABLE I – FUNDAMENTAL ABILITIES NECESSARY TO DO SCIENTIFIC INQUIRY (NATIONAL RESEARCH COUNCIL, 2000, P. 19)

Defining the list not as necessary abilities, but as aims in the science classroom, could offer a shift in perspective. On top of that, deficits should rather be considered as developmental areas. The core idea of this change in perspective is that the school system has to provide resources and the teachers should look for strategies and approaches so that students can make learning progressions. It is not the student who must prove to be includable. Inquiry-based teaching could provide learning opportunities for special needs students to develop some of the competencies (cp. table 1) and to foster them according to their needs. However, the positive attitude and substantial education of teachers is extremely relevant to reach this goal (Norman, Caseau & Stefanich, 1998).

The expert group of the European Commission (2007) recommends inquiry-based teaching for students across the ability range. There is a limited body of research on IBSE supporting this claim related to students with cognitive and emotional/behaviour disorders.

Bay, Staver, Bryan, and Hale (1992) compared direct instruction and discovery teaching in their study in terms of science achievement, the retention of the achievement, generalisation of science process skills and hindrance of no handicapped students. Ten students were diagnosed as having cognitive disorders, six students as having behavioural disorders. All were integrated in general education classes. The results showed no advantage for one of the approaches concerning science achievement. But «students' retention after two weeks was higher for those who received the discovery instruction» (Bay et al., 1992, p. 567). This is unsurprisingly not the case for the students with learning disabilities, because of their cognitive pre-conditions. However, the learning disabled students receiving discovery teaching scored better in the generalisation test than their counterparts with direct instruction. Against a common expectation, the achievement of no handicapped children was not hindered because of the integrated students. This study suggests that discovery learning approaches can be appropriate for students with cognitive and behavioural disorders; at least they are not obstructive for learning.

McCarthy (2005) compared a science textbook instruction with a hands-on approach in two classrooms where students with serious emotional disturbances were integrated. The researcher was interested in the effects on students' behaviour and achievement. Concerning achievement, the students who were taught with the hands-on approach performed significantly higher in the achievement tests. No difference was observable in terms of student behaviour.

In the study of Mastropieri, Scruggs, and Butcher (1997) normally achieving students were compared with students with learning disabilities and students with mental retardation (assessed by their teachers and IQ-tests) in an inquiry-based learning environment. Students were «coached and prompted to provide a general rule using inductive thinking» working on a physics task (ibid., p. 9). As expected, the students with learning disabilities scored between the other two groups of students in the generalisation tasks and needed fewer coaching than the students with mental retardation, but more coaching than the normally achieving students. The authors suggest that students with learning disorders can participate and benefit from inquiry-based learning, but need well-structured support. Ten and more years later and on the basis of many more investigations the researchers come to similar conclusions. Constructed and instructed learning approaches have both shown their applicability. The implementation is always depending on the learning aims strived for which do not have to be the same for every student. Subject-specific aims should be different while educational aims should be the same (Hinz, 1996). If inquiry-based settings are chosen, students with special needs will need an appropriate amount of coaching (Scruggs & Mastropieri, 2007). «When instruction is appropriately presented and modified, students with learning disabilities are very successful at mastering science content« (Brigham, Scruggs & Mastropieri, 2011). The case study of Sullivan Palincsar et al. (2001) contributes to understand the learning opportunities students get when participating in a guided inquiry-based setting. All students, also those with special needs, made significant learning gains when scaffolded by teachers with advanced strategies, i.e., «(a) monitoring and facilitating student thinking, (b) supporting print literacy, and (c) improving working in groups» (Sullivan Palincsar et al., 2001, p. 24).

Two reviews and a meta-analysis about studies in this field summarise that IBSE is only benefiting for students with special needs when it is carefully structured and scaffolded (Scruggs, Mastropieri & Okolo, 2008; Therrien, Taylor, Hosp, Kaldenberg & Gorsh, 2011; Villanueva et al., 2012).

One strategy of scaffolding is to implement inquiry-based learning successively to give students the chance to acquire the needed skills (see table 1) stepwise, thoroughly and without excessive demands. This procedure allows them to develop a feeling of autonomy and competence (Deci & Ryan, 2000). «It is important that learners develop basic learning techniques for autonomous study. Those have to be extended in class step by step» (Wodzinski & Wodzinski, 2009, p. 146).

To fulfil this demand in school the levels of inquiry-based learning can be applied (Abrams et al., 2008; Schwab, 1964). The higher the level of inquiry, the higher the level of responsibility placed on students. The explicit instruction of the teacher is gradually reduced with each level (table 2).

| | Source of the question | Data collection methods | Interpretation of results |
|---|---|---|---|
| Level 0: Verification | Given by teacher | Given by teacher | Given by teacher |
| Level 1: Structured | Given by teacher | Given by teacher | Open to student |
| Level 2: Guided | Given by teacher | Open to student | Open to student |
| Level 3: Open | Open to student | Open to student | Open to student |

TABLE 2 – THE LEVELS OF INQUIRY
(BLANCHARD ET AL., 2010, P. 581)

Students with no or little experience should start with an inquiry level 0 and acquire more and more competencies stepwise to work successfully on the other levels. «Instruction should gradually and systematically move from Level '0' activities with the ultimate goal being some Level '3' activities» (Lederman, Southerland & Akerson, 2008, p. 32).

However, in special education level 3 is not automatically the optimal level to be achieved for every student (Abels, 2012a). The levels should be applied appropriately in terms of context, e.g. aim, situation, students' pre-conditions and experience, topic, etc. Some students need a lot of structure and support. Having implemented a set of tools on level 0 and having enhanced the competence to draw conclusions on level 1, level 2 is often the most appropriate level in the long run offering a mixture of adapted structuring and openness. A balance between openness and structure has shown to be effective for students with cognitive and emotional/behaviour disorders (Werning & Lütje-Klose, 2007). That is why Scruggs et al. (2008) recommend guided inquiry on the basis of their studies. The following table shows a list of aims for each level which can be focused level by level. Developing the skills successively and in teamwork is supposed to increase students' feeling of autonomy, relatedness and competence (cp. Deci & Ryan, 2000).

The core skill to do open inquiry is being able to ask scientific questions. This is regarded as a complex and challenging task. Students have to be enabled to ask scientific questions to do open inquiry. Hofstein, Navon, Kipnis, and Mamlok-Naaman (2005) distinguish low-order and high-order questions. «[H]igh-level-type questions (…) are questions that can be answered only by further investigation, such as conducting another experiment or looking for more information on the Internet or in chemistry literature. These ques-

<table>
<tr><td>Level 0</td><td>• To be acquainted with devices (pH meter, thermometer, …)<br>• To conduct certain practices (to titrate, to filtrate,…)<br>• To follow safety guidelines<br>• To follow descriptions of experiments, etc.</td><td rowspan="4">Feeling of Autonomy, Relatedness and Competence</td></tr>
<tr><td>Additionally on Level 1</td><td>• To observe<br>• To document observations and interpret them in the team<br>• Apply knowledge to come to conclusions and judgements<br>• To justify conclusions with evidence-based arguments<br>• To present and discuss results, etc.</td></tr>
<tr><td>Additionally on Level 2</td><td>• To hypothesise<br>• To plan and conduct experiments<br>• To consider influencing factors, e.g., to decide about quantities, devices etc. and justify decisions<br>• To control variables<br>• To justify the experimental design<br>• To match results with hypotheses<br>• To change the experimental design reasonably, etc.</td></tr>
<tr><td>Additionally on Level 3</td><td>• To ask scientific questions<br>• To take responsibility for the whole investigation process, etc.</td></tr>
</table>

TABLE 3 – AIMS OF INQUIRY LEARNING LEVELWISE

tions are more complicated, and the student has to think critically about the research to be able to pose them» (ibid., p. 8). Question stems can help students to phrase questions which do not just ask for facts (Neber & Anton, 2008).

There are more strategies of scaffolding which can support inquiry learning. These strategies are mentioned in the following list with further reading advice.

- Teaching mnemonic strategies is effective as students can recall vocabulary and thus have more capacity to learn science concepts (Scruggs & Mastropieri, 2000; Scruggs et al., 2008; Therrien et al., 2011).
- Spooner, Knight, Browder, and Smith (2012) identified task analytic instruction with systematic prompting and feedback as well as time delay as evidence-based practices to support students with disabilities (cp. also Browder et al., 2012).
- Graphic organizers «improve the factual comprehension and vocabulary knowledge of intermediate and secondary students with LD [learning disability] in science» (Dexter, Park & Hughes, 2011, p. 210). They also facilitate longer maintenance of scientific knowledge (ibid.).
- Peer-tutoring has shown to be very successful in supporting students with cognitive disorders (Jimenez, Browder, Spooner & Dibiase, 2012; Scruggs & Mastropieri, 2007).

- Text enhancements, vocabulary learning and other language strategies support a diverse student group in comprehending a science concept and conducting an inquiry (Bakken, Mastropieri & Scruggs, 1997; Markic & Abels, 2013; Mason & Hedin, 2011). Word and picture symbol cards were also shown to be supportive (Browder et al., 2012)
- Targeted questioning by teachers or peers helps students to draw inferences and come to higher levels of comprehension compared to just providing them the knowledge (Mastropieri et al., 1997).
- Differentiated materials enable students of different achievement levels to work on the same topic (Abels & Markic, 2013; Tobin & Tippett, 2013).

Inquiry-based learning environments can be varied in length, complexity, task, responsibility etc. Groups of students can do parallel work on different levels supported by different strategies (Abels, 2012a). The teacher can provide material, guiding or targeting questions, hint cards etc. which can be used by students who need support. Using the provided help reduces the openness of inquiry, but allows everyone to participate in the task. These aspects make inquiry-based learning suitable for students with different cognitive and affective pre-conditions. Additionally, general education students are not hindered in their learning (Bay et al., 1992). Even more, what is good for students with special needs is beneficial for all students in the (science) classroom (Meijer, 2010; Steele, 2004).

## IBSE IN AN INCLUSIVE CLASSROOM – A CASE STUDY REPORT

The European Agency determined seven factors which are crucial for inclusive education in the secondary setting. A combination of factors makes a setting even more inclusive (Meijer, 2005, 2010). The factors are

- Co-operative teaching (i.e., cooperation between teachers in- and outside of school),
- Co-operative learning (i.e., peer tutoring),
- Collaborative problem-solving (i.e., clear class rules and behaviour strategies agreed with the students),
- Heterogeneous grouping (i.e., differentiation and absence of homogeneous grouping),

- Effective teaching (i.e., systematic monitoring, assessment, evaluation and feedback, individual education plans),
- Home area system (i.e., two or three classrooms per learning group with a consistent team of teachers), and
- Alternative ways of learning (i.e., learning to learn and teaching students to learn autonomously).

For the case study presented here an urban lower secondary school was chosen that fulfilled more than one of these factors. The school is an inclusive middle school from grade five to eight. In every class four to five students with special needs are officially integrated. Extra resources are provided in terms of an integration teacher. Help by volunteers (teacher students, retirees, other guests) is always welcome. About 20 students are grouped into one class. Every student is seen as having particular learning needs. Parents choose the school because of the effective support every student receives, not only the students with diagnosed special needs. There are consistent teacher teams responsible for one age-group level. Systematic monitoring and evaluation are organised in cooperation with the education authority and the university. Alternative ways of learning and assessment are established, also in science (Minnerop-Haeler, 2013).

The most innovative approach to establish an inclusive learning culture in science is a *Lernwerkstatt*. The concept was originally developed by Karin Ernst in Berlin, Germany, in 1980. It is mainly based on the New York workshop centre developed by Lillian Weber (Ernst, 1996; Weber, 1977). As there is no appropriate translation the term *Lernwerkstatt* will be used in the following. «A Lernwerkstatt is described as a room where learners encounter stimulating phenomena, objects and materials which are supposed to trigger questions in their own field of interest (…) to start immediately with an inquiry» (Puddu, Keller & Lembens, 2012, p. 154). *Lernwerkstatt* can be classified as open inquiry which is accompanied by coaches who scaffold students' inquiry learning process (Hagstedt, 2004; Zocher, 2000).

The inclusive middle school which is in the focus here has an own room designed as a *Lernwerkstatt* where students have access to inspiring materials, objects and phenomena (Minnerop-Haeler, 2013). Every class in the school has one *Lernwerkstatt* per year lasting three days. Given are the topic and scenery of materials and phenomena which encourage the students to find their own questions and hypotheses. This classifies the setting as an open inquiry approach.

figure 1 – scenery with materials in the lernwerkstatt «light and colour»

Prescribed topics are, for example, light and colour, water, insects etc. (figure 1). Together with the coaches the students find a question, plan and conduct experiments and document their ideas and observations in a lab journal. Coaches are the *Lernwerkstatt* teachers, the classroom teachers who join the *Lernwerkstatt*, higher education students or assistant teachers. At the end a festivity is arranged by the students to present their own results (Minnerop-Haeler, 2013).

The two teachers leading the *Lernwerkstatt* were desirous of reflecting the open inquiry setting to make the learning even more effective for the students according to the aims of inquiry learning (see table 3 above). This positive teacher attitude is one of the success metrics of the school (cp. Norman et al., 1998). To have a basis for the reflection, all classes working in the *Lernwerkstatt* this school year were and will be videotaped. Additionally, the teachers wore audiotapes to record their scaffolding. Student interviews and the lab journal will function as a third and fourth database. The reflection of the video scenes is in the focus in this paper. Video sequences were chosen by the author and reflected together with the teachers to develop alternative approaches during the *Lernwerkstatt* so that the students' autonomous learning can be improved.

## THE VIDEO SCENES

The research project is currently in a starting phase. First rounds of data collection and analysis have started in accordance with a Grounded Theory approach (Corbin & Strauss, 1990). The article at hand focuses on the first reflective meeting with the two *Lernwerkstatt* teachers.

FIGURE 2 – CLUSTERING OF STUDENTS' QUESTIONS

Two video scenes were chosen for this meeting recording the beginning of the *Lernwerkstatt* where students are supposed to find their research question. The topic was light and colour in grade eight who had *Lernwerkstatt* for the third time. 20 students of one class participated in this *Lernwerkstatt*, ten boys and ten girls. Five students officially had special needs, three girls and two boys, reaching from severe to mild disabilities, from mental retardation to autism to ADHD and emotional/behavioural issues. But there are more students with special needs although not diagnosed. According to the teachers every student has particular learning needs. Four coaches were present to support the students: the two leading teachers, the classroom teacher and a school assistant. The researcher and her diploma student were also fixed with scaffolding two groups of students. Every coach except the diploma student knew the class from other lessons to a different extent. One of the leading teachers is the science teacher in this class.

The first video scene selected by the researcher shows how the students presented all the questions they framed after walking through the scenery of materials and phenomena. The teachers clustered the questions among umbrella terms (green cards, see figure 2).

Each student phrased between one and about 15 questions. The students phrased, for example, the following questions:[2]

- How does a laser pointer operate?
- How far does reflected light go?
- Can light be transformed to electricity?

2 All translations were made as close as possible to the original wording.

- Why are some creatures attracted by light?
- Why is light so important?
- How fast is light?
- What would happen if the sun had another colour?
- Why is the world so colourful?
- Who discovered the colours?
- And many more …

The second video scene shows which topic or questions the students finally chose and how the decision process ran. Topics respectively questions chosen were, for example:

- What is a rainbow?
- Gain of energy out of light
- The colour blue
- How do colours affect us?
- Reflection of light with mirrors
- To build a kaleidoscope
- To dye food
- (…)

These two scenes were chosen for a first reflective meeting with the two teachers, because the phase of phrasing and finding scientific questions is regarded as extremely challenging, and at the same time crucial for starting with an open inquiry (cp. Hofstein et al., 2005).

Both phases, the collection and clustering of questions and the selection of a topic, had conducive and obstructive aspects for students' learning processes. From the researcher's point of view fostering elements were the following:

- Students phrased questions self-dependently,
- The interest of the students was pivotal,
- Some questions were already high-order questions which was made visible,
- There were a lot of why-questions making students' conceptions explicit,
- Exciting questions were posed which were all asserted and appreciated,
- The appreciative attitude of the teachers,
- The growing collection of questions on the wall as a joint project,

- The possibility to learn from each other and to get aware of each other's interests,
- To divide into groups autonomously, and
- To choose a question/topic by oneself.

From the researcher's perspective obstructive aspects were, for example, that the phase of clustering questions was very long (>20 minutes) demanding a lot of attention and patience from the students. Furthermore, the mental work was actually done by the teachers by clustering the questions on the wall and finding umbrella terms. Only one of the students was active at the moment of presentation. The others tried to stay calm or whispered with their neighbours. The students have to be praised for their perseverance, but had to be exhorted from time to time by the teachers:

T1:[3] I think it's a pity that you don't really listen and just watch there what questions people found.

T2: I believe that they are so enthusiastic about <u>their</u> questions and busy with them, you are allowed to tell them immediately, ok?

The aim of the phase of presenting questions and the added value for the students stayed unclear or implicit, especially because the majority of the students chose a topic later on to work further with instead of their original questions. Some of the students' questions were not even allowed to be chosen but it is not explicitly said why. Additionally, it was unclear how many students could work together on the same topic. A girl putting her hand up first asked how many students could work together in one group. Teacher 1 said, «We will see.» This caused problems which will be shown in the following videotaped and transcribed plenum conversation. The outtake shows the parallel negotiation about topics and group size based on implicit rules.

$S_m1$: I would like to with $S_m2$, $S_m3$ and $S_m4$, well//

T1: //in a group of four

$S_m1$: //the topic to make construct a laser.

3 The leading teachers are abbreviated with T and a number. Students are abbreviated with S, m for male and f for female and a number. The school assistant is indicated by Ass., while the classroom teacher is abbreviated with CT. Emphasised words are underlined, breaks are indicated by (-), one hyphen per second. Double slashes show that persons cut in.

$S_m2$: to construct a laser

T1: Well, in a group of four, what do you want now, my question is, do you want to construct a laser?

$S_m2$: Yes. We wanted to see ourselves//

T1: Eh, I tell you immediately, doesn't work.

$S_m2$: We want to see, well, how it is constructed and, well, we wanted to rebuild a laser ourselves.

T1: You are not able to do it here. That's not working. That that doesn't work by any means. That doesn't work. Ok, I can tell you immediately, that doesn't work. To construct a laser pointer doesn't work.

$S_m5$: I have a question.

T1: Yes?

$S_m5$: I have a question. Why does this not work?

T1: Because we do not not have (--) things for this.

Ass.: No mirrors, no lenses, no strong light//

T1: //That doesn't work.

CT: If you do not know what you are doing, it can blow up in somebody's face//

T1: //doesn't work. Well, building a laser pointer doesn't work by any means. Ok? So. Think about it, please, ok? $S_f1$?

$S_f1$: Eh, us four, we wanted to do the topic rainbow.

L2: Ok, guys, you know from last year, four people are not working.

CT: And above all, yes, there is only laughter and//

T1: //No, well, two people rainbow is ok. But four, or two times two different groups, yes, but a group of four surely doesn't work.

The aim of the reflective meeting was to see which conducive and obstructive aspects the teachers would identify as well as to develop alternatives together for the processes of presenting and choosing research questions. This reflective process is organised in accordance with the ALACT model (figure 3). Step 1 was videotaped, step 2, 3 and 4 were conducted during the meeting. Step 5 is supposed to happen during the next *Lernwerkstatt*. Reflection is seen as a key element for improvement of and for lasting changes in teaching practice as well as congruent teaching (Abels, 2012b; Swennen, Lunenberg & Korthagen, 2008; Zeichner & Liston, 1996).

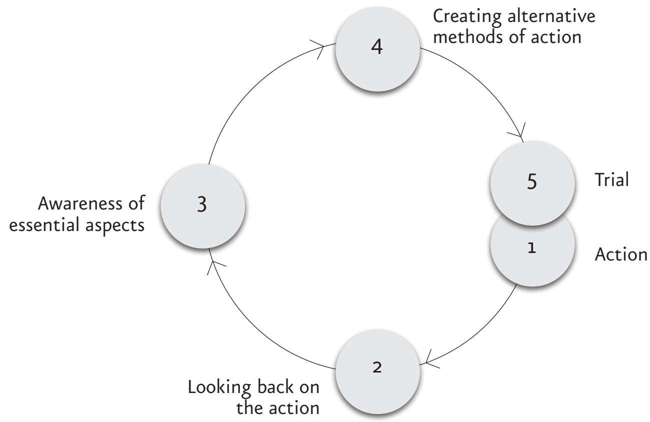


FIGURE 3 – THE ALACT MODEL DESCRIBING THE INTENDED PROCESS OF REFLECTION (KORTHAGEN, LOUGHRAN & RUSSELL, 2006, P. 1028)

## THE REFLECTIVE DIALOGUE WITH THE TEACHERS

The reflective conversation with the teachers was intended to be a dialogue, not an examination. It lasted 102 minutes and took place three months after the *Lernwerkstatt*. The teachers expressed how helpful it is to see oneself with a distant view on a video. Before watching the videos, the teachers were asked to exchange what mostly returned to mind. Among other things, they highlighted two groups of male students with their research projects and the variety of questions presented especially by the girls.

Afterwards the first video scene about clustering the students' questions was watched almost in full length (>20 minutes). One teacher (T2) said right after the video started that this phase was one of the most exciting ones, but also the most difficult one. After three-fourths of the students were seen presenting their questions, she realised:

T2: This is really a long phase that demands a lot from the children. To listen. I do not really have another idea how one could shorten it.

R:[4] Shall I stop it [the video scene] here or do you want to watch it until the end?

T2: As far as I'm concerned stop.

4 R = Researcher.

The teachers were asked to express their first impression or feeling. Although they were concerned about the length of the phase, they emphasised the importance of this clustering. They assumed that the students realised what their classmates said despite mumbling. Beyond that they assumed that the mumbling students talked about the presented questions. The teachers pointed out that the exchange between the students was essential. Additionally, from the teachers' view it was important to learn to listen to each other. A conflict between appreciation and structuring occurred here. The teachers strived for valuing the ideas of every student, but felt the need for shortening the phase which was perceived as being contradictory for their internal aim of appreciation.

A first alternative approach they came to think about soon is that the students could cluster themselves and write the umbrella terms on the green cards. But this would even prolong the process of clustering. The researcher contributes a new perspective:

R: What I thought about is who is really active in this phase, who really has to think.
T2: Well, us two.
R: (laughs) Exactly. A lot of work is done by you two. You cluster and you write the umbrella terms.
T1: This means to involve the students here more.
T2: Yes, that they get an assignment. That they get an assignment.
R: Yes, the students who sit in the circle//
T2: //do not have an assignment.
(…)
T2: They really do not have an assignment. That blows my mind.

The teachers developed more and more ideas how to change this phase, e.g., one student could read his/her questions and two others would join the student and cluster the cards so that three students could participate actively. The researcher suggested the idea to present the questions not student-wise, but topic-wise. One student would read aloud a question and everyone would have to pay attention if he/she wrote a similar one that had to be pinned on the wall. The teachers picked up on this idea and developed a whole scenario how they could instruct the students during the next *Lernwerkstatt* enabling them to do the clustering themselves. Students would have to get up more often and pin their questions on the wall. Teacher 1 mentioned that this benefits especially the ADHD students.

This was the only time the teachers mentioned the students with special needs. They were mostly concerned about all students and how to handle the group as a whole.

After the approving reaction of the teachers to the first ideas the researcher mentioned another aspect.

R: What I also thought about what one really writes on the green cards. The students showed a remarkable performance (…). They almost all wrote questions.

T1: And we just slapped a headline. (all are laughing)

The teachers got aware of the fact that the green cards represented topics, not the students' original questions. Accordingly, teacher 1 suggested phrasing questions instead of headlines on the green cards. She further developed the idea to leave the cards blank and that the students should develop the core question per cluster in groups. A coach could already scaffold this part of framing the core question with a group of students who are interested in working on the associated inquiry. The teachers summed up that this change would lead to higher participation and self-dependency for the students not decreasing the appreciation. The gained time could be used to discuss with the students how they would proceed with planning and conducting an experiment. The researcher emphasised the released resources for the teachers who could concentrate more on scaffolding the process instead of doing the mental work.

These considerations led to look at the next video scene about the selection of a topic. The teachers confirmed again that the students talked about topics, not questions. Teacher 1 said that she is stressed out by the boys discussing about the laser pointer. Teacher 2 expressed her helplessness how to scaffold the students to find a question. The phase was perceived as so important that it caused a high stress level. The researcher phrased her admiration for the teachers' management of this difficult phase as in the end every student chose a topic and was able to work. Teacher 1 realised that the new ideas developed in the reflective conversation before could make the selection phase much easier.

Subsequently, the researcher formulated her observation about implicit rules. She perceived it as unclear which topics were decent and which group size was allowed. Both teachers agreed. They had certain implicit ideas and experiences how to proceed with some of the suggested topics. They did not expect the boys' idea to build a laser and foresaw a risk of injury. The teachers discovered a contradiction. Usually, in the classroom laser pointers are forbidden. In the *Lernwerkstatt* scenery laser pointers were exposed, but to work with them how the students intended to do was forbidden. Thus, it was not understandable for the students why they were not allowed to choose this inquiry as they were used to and appreciated – on their own admission – to work self-dependently in the *Lernwerkstatt*. They opposed the restriction when $S_m5$ launched a discussion: «I have a question. Why does this not work?» (see transcript above).

With other groups of students there was no discussion about the topic although it was not precise and although more than two persons wanted to work together. This happened especially with groups of girls and with a group of girls with mental retardation:

T1: $S_f2$, please.
$S_f2$: Eh, we want, we want//
CT: // $S_f3$ and
$S_f2$: $S_f3$ and $S_f4$ on the colour blue
T1: The colour blue, ok

The researcher's hypothesis is that the teachers know the special needs students and had ideas in mind how to proceed with them during the practical phase, mostly focusing on painting and crafting. Furthermore, they knew which groups of girls can be trusted to work in bigger groups than two. These hypotheses have to be further researched.

Another topic the researcher introduced dealt with researchable questions. During a discussion about the laser teacher 2 appealed to two boys transcribed from the video scene:

T2: I would like to say that you when you start with the group work, you have to think about which questions do you want to pursue and what can we inquire here and how eh do you really have a topic to fill two days of work.
CT: Otherwise it is such a big topic, yes?
T2: You have to think about that if that works. I put your names here and

then it is, have you thought a little bit more about it or are you only fascinated by the devices. You have to think about that. Yes? Are there enough possibilities for you right now and here to do research with our resources.

$S_m5$ and $S_m6$: Yes.

T2: Ok. (puts the names on the board)

The teachers perceived that they let the students do inquiry, but there was not an opportunity to learn something about inquiry explicitly (cp. aims according to Abrams et al., 2008; see above). They started to develop a list of criteria about «good» questions that could lead to further inquiries which were realisable with the prerequisites in the school and asked the researcher to provide some hints from the literature. They made suggestions how to integrate this meta-discussion into the *Lernwerkstatt* process.

Finally, teacher 2 summarised three alterations to be implemented next time:

T2: When we prepare the insects [next Lernwerkstatt topic] then we will talk about what researchable questions are in school. I like that. To mind the groups, the group formation. And try out this thing during the cluster round. I want to try these three things. Those will be effective, I think.

The researcher and the teachers noted that this dialogue was very intensive, but very effective as well. They agreed on meeting again after the changes were implemented (step 5 of the ALACT model, see figure 3).

Most of the ideas for change were initiated by the researcher who had time to prepare the session. The teachers captured the suggestions and developed them further. Next time the teachers should also watch the selected videos before the meeting and note their ideas beforehand.

## CONCLUSIONS

Most remarkable is that the students with cognitive and behaviour/emotional disorders were not identifiable during the *Lernwerkstatt*. They worked in different groups of students and were fully included. Also the girls with severe mental disabilities could participate in this setting. Because of the teachers' experience and the possibility of intensive coaching they could also work on topics in the field of «light and colour». However, it was obvious that the teachers demanded more specific topics or questions of the general education students and students with mild disabilities. They did not treat the latter differently because of their special needs status. The *Lernwerkstatt* is a setting that facilitates equal learning opportunities for all students.

However, in terms of learning to do inquiry and learning about inquiry the learning opportunities could be improved. The teachers developed together with the researcher three important steps to increase the possible learning gain for all students:

1. Students will cluster their questions topic-wise instead of teachers doing the mental work. The students are supposed to find core questions instead of umbrella terms.
2. There will be clear rules for group formation.
3. A criteria list for researchable questions will be developed and discussed with the students.

After the implementation of these actions there will be another reflective meeting to question the success. It has to be evaluated if the level of appreciation which is so important for the teachers can stay comparably high while increasing the structuring elements.

One major observation is that the teachers struggle more with the implementation of IBSE than with aspects of inclusion. There could be a relation to their aims which are more on the educational side than on the subject-specific side.

The present research project will be extended by analysing the *Lernwerkstatt* of other classes, the regular science course as well as other cases to give more detailed insight in the field of inclusive science education.

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