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INQUIRY-BASED LEARNING ENVIRONMENTS TO WELCOME THE DIVERSITY OF A CHEMISTRY CLASS

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Abstract: Inquiry-based learning environments have the potential to deal with the diverse learning needs of students surfacing also in science classrooms. As inquiry-based science education facilitates the engagement of students across the ability range, it is often recommended by experts in science education. Despite this widespread acceptance among researchers, however, this approach does not feature extensively in many school curricula and science classrooms. Suitable inquiry-based learning environments have to be designed and successively implemented in science classrooms according to the students' individual needs to welcome their diversity. Accompanying research is needed to determine the conditions that are conducive and relevant for successful implementation of inquiry-based learning environments in diverse science classrooms. We have decided to take a closer look at this question at classroom level to be highly detailed about the conditions surfacing in a diverse science classroom. A case study has thus been carried out with a group of ninth-grade urban business school students to observe and analyze the challenges to be dealt with in a diverse class when implementing inquiry-based learning. Besides video and audio recordings, field notes and interviews, the questionnaire "Views on Scientific Inquiry" (VOSI) as well as questionnaires concerning academic self-concept and attitude towards science were used. In addition, the students' task sheets enrich the dense picture we have gained of the inquiry-based work done in this diverse class. The results of the case study show specifically how important it is for a teacher to know the students' individual learning needs and how to scaffold the inquiry-based learning tasks in relation to the students' language and attainment levels. Student diversity will be illustrated in detail by the empirical data and it will be shown how the teachers welcomed their diverse needs with inquiry-based learning environments.

Keywords: inquiry-based science education, diversity, case study

RATIONALE

Induced by general policy documents, e.g. the Salamanca Statement and Framework for Special Needs Education (1994) and the UN Convention on Rights of Persons with Disabilities (2006), international demand for dealing with diversity in schools and for inclusive learning environments is high. As globalization prompts migration and demographic changes to national populations, diagnosing and dealing with students' diverse needs is considered one of the biggest challenges in many European schools (Meijer, 2010). In this context, "diversity" not only means differences in mental and physical ability, but also differences in gender, ethnicity/nationality, age, sexual orientation and religion (Krell, Riedmüller, Sieben, & Vinz, 2007). Teachers are required to address these differences in each subject as they impact students' motivation, achievement, interest, ways of learning they are used to, prior knowledge they bring to class, and language skills (Bohl, Bönsch, Trautmann, & Wischer, 2012). To support all students as best as possible a stance of welcoming diversity is needed. A paradigm shift is demanded from an integrative to an inclusive system where difference is seen as a resource for learning rather than a problem, where strength are focused rather than weaknesses and where resources are provided systemically and not individually (Sliwka, 2010).

Also in science education, expert recommendations – primarily the so-called Rocard Report (European Commission, 2007) – focus inter alia on learning environments that facilitate student engagement across the ability range. The report especially assigns inquiry-based learning (IBL) environments the potential to deal with students' diverse learning needs. This assignment can be supported by various empirical studies comparing constructed versus instructed learning in diverse classrooms (e.g. Bay, Staver, Bryan, & Hale, 1992; Lee, Buxton, Lewis, & LeRoy, 2006). But "although the science education community recognizes inquiry as a centerpiece of science teaching and learning, many teachers are still striving to build a shared understanding of what science as inquiry means, and at the more practical level, what it looks like in the classroom" (Luft, Bell, & Gess-Newsome, 2008, p. vii). This common ground fully comes to fruition when teachers are asked to implement IBL addressing the diverse needs of their students.

To meet the described challenges, in addition to comparing learning environments on a larger scale, science education research has to provide detailed insight into which conditions facilitate successful implementation of IBL in a diverse science class. Thus, a closer relation between research results and classroom practice shall be achieved, which would help teachers to design and conduct IBL environments that welcome their students' diversity. We have taken on this task for our case study.

RESEARCH DESIGN

The study at hand can be classified as a case study (Yin, 2009). The "individual unit" (Flyvbjerg, 2011) is a ninth-grade chemistry class at an urban business school (31 students taught by two chemistry teachers) which was accompanied by researchers for one school-year. To implement IBL the laboratory class was chosen by the teachers, which took place for 150 minutes every three weeks.

The core of implementing IBL is its successive introduction, which "should gradually and systematically move from Level '0' activities with the ultimate goal being some level '3' activities" (Lederman, Southerland, & Akerson, 2008, p. 35). The higher the level of IBL, the higher is the level of student responsibility and autonomy (Table 1).

Table 1

The levels of IBL (Blanchard et al., 2010)

	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

The objective of the laboratory classes was to introduce IBL successively starting with level 0 orienting the activities to the prior skills of the students. It was aimed to reach level 3 halfway through the academic year. Afterwards the levels of the tasks varied depending on the goals to be achieved.

The research questions of the case study complemented by the relevant data sources and expected outcomes are outlined in Table 2.

Table 2

Research design

Research questions	*Data sources*	*Expected outcomes*
1a) What are the learning needs and subject-specific prerequisites of the class? 1b) Which individual learning needs and subject-specific prerequisites are striking?	• Video and audio recordings, • participant observation, • teacher interview, • questionnaire concerning demographic data and academic self-concept (Dickhäuser, Schöne, Spinath, & Stiensmeier-Pelster, 2002), • VOSI plus student interviews (Schwartz, Lederman, & Lederman, 2008), • questionnaire concerning views on science (OECD, 2006), • class register	Diverse learning needs and subject-specific prerequisites on both classroom and individual levels by "thick description" method (Geertz, 2011) System of categories by structuring the answers on the development scale "naïve" – "transitional" – "informed" and "no answer" (Schwartz et al., 2008)
2) How do the teachers consider the learners' needs while conducting IBL?	• Video and audio recordings, • participant observation, • task sheets, • teacher interview	Conducive and obstructive conditions for the implementation of IBL in a diverse science class by inductive coding (Mayring, 2007)

FINDINGS

To achieve a "thick description" (Geertz, 2011) of the learning needs and subject-specific prerequisites of the class (ad research question 1a), we mainly used the video and audio recordings, participant observation protocols, the class register and questionnaires as a database (see table 2). The following table provides some insights into the most striking diversity dimensions found in this class.

Table 3

Class description (extract)

Class description	
Number of students	31, 7 drop out during school year, 5 female and 2 male students
Gender	20 female and 11 male students; some issues concerning gender maybe due to cultural reasons
Language	14 different mother tongues; the Serbo-Croatian language group is mainly represented in this class; when working in small groups students choose partners in accordance with sex and language
Migration	28 out of 31 students have a migration background
Age	The age distribution comes to three years and one month; at the beginning of the school year the youngest student was 13 years and eleven month; consequently, the developmental stages differ immensely
Social background	Overall low
Class climate	fickle, depends on form of the day; teachers have to be careful with mental overload, students are motivated as long as they do not feel overchallenged; some students' frustration with their school careers thus far is highly noticeable in various behavioral disorders
Skills needed for inquiry-based learning	performance level, commitment, and working speed are highly diverse; lab journal shows different linguistic prerequisites; a lack of reading competences means that tasks are often not understood; it is difficult for the students to state hypotheses and to plan experiments; they can conduct experiments, but drawing conclusions is hard; using theoretical concepts during practical work is a challenge for many students
IQ	In dependence of age: 101 (average), range from 66 to 124, tested with the CFT-R with 18 out of 31 students
Academic self-concept	Mean value 3.60 on a 5-Likert-scale (22/31 students), range from 1.20 to 5.00 (Dickhäuser et al., 2002)
Views on Science questionnaire	Enjoyment of science (JOYSCI) 2.61, General value of science (GENSCI) 2.87, Science activities (SCIACT) 1.70, Interest in science learning (INTSCI) 2.47 (PISA questionnaire 22/31 students; 4-Likert-scale, 4: agreement, 1: disagreement)

To get a deeper insight into the students' views on scientific inquiry the VOSI (Schwartz et al., 2008) was conducted at the beginning and at the end of the school year. Only 16 students who filled out the first VOSI questionnaire also completed the second one. Thus a comparison between the first and second questionnaire is only possible for them (Figure 1). Deductive categories used for the structured analysis (Mayring, 2007) are also drawn from Schwartz et al. (2008).

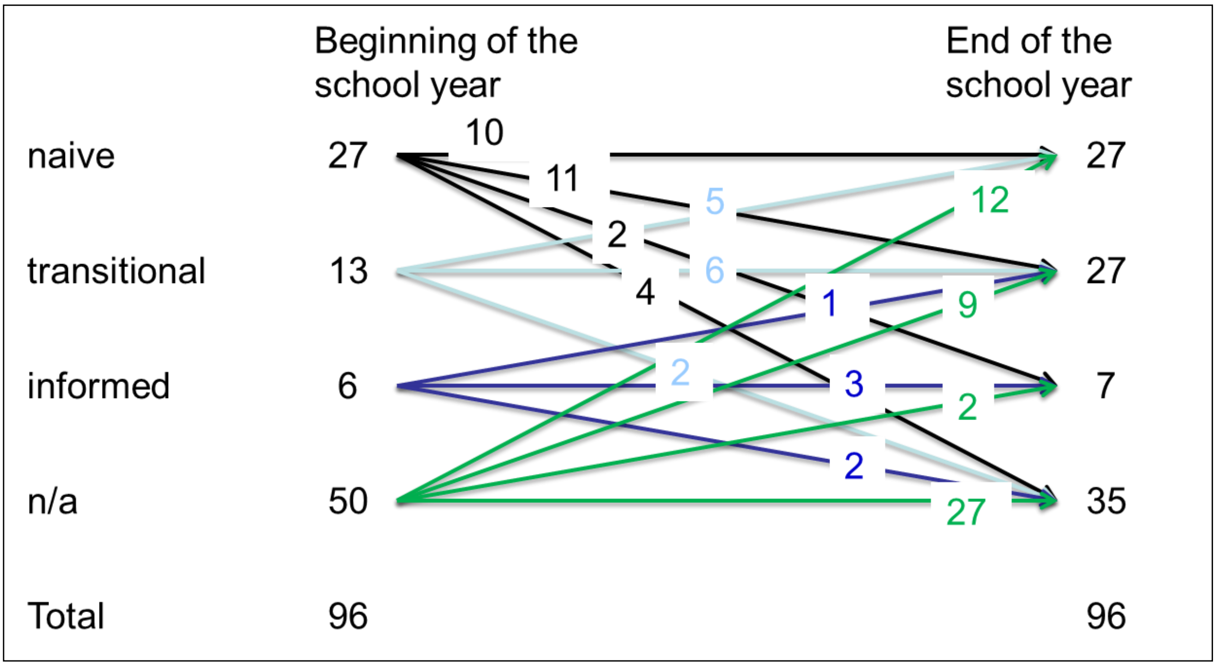

Figure 1. Comparison between the first and the second VOSI questionnaire

The development of the answers can be seen as positive by tendency: at the end of the school year the students tend to give more (elaborate) answers. But the figure 1 also shows a very diverse picture. Thus, we decided to have a closer look on individual students (ad research question 1b: Which individual learning needs and subject-specific prerequisites are striking?). The same database was used. Exemplarily, we chose Dana[1] to be introduced here and to better understand the diverse picture we won of the class.

At the beginning of the school year Dana was 14 years and one month old. Her Nationality is Austria and her mother tongue is Serbian. Her IQ analyzed with the CFT-R is 102 which can be considered as an average value depending on her age. Her academic self-concept test (Dickhäuser et al., 2002) shows a mean value of 4.4 on a 5-Likert-scale. In the questionnaire she agrees, for example, to know much in chemistry and that many tasks are easy for her to solve. However, the Views on Science questionnaire (4-Likert-scale; 4: agreement) does surprisingly not support this positive image of science learning:

- Enjoyment of science (JOYSCI): 2,6
- General value of science (GENSCI): 3,2
- Science activities (SCIACT): 1,7
- Interest in science learning (INTSCI): 2,5.

To understand the results of the standardized instruments the results of the analysis of the observational data were added. Her participation in classroom can be described as follows: On the one hand, Dana talks private stuff most of the time, she seems to sleep in the lab class from time to time or she plays with her phone. On the other hand, she asks well-conceived questions, discusses a lot of the scientific tasks with her classmates as well as with the teachers and provides ideas for problem solving. Thus, there seems to be no direct connection between her interest in the subject, her self-concept and her engagement in laboratory work.

If we look on the results of her VOSI questionnaire there appears to be no change according to the coding manual (Table 4). The answers in the pre-test which was conducted in September were coded on the same level as the answers in the post-test in the following June after one school year.

Table 4

Dana's results of the VOSI questionnaire

Categories	*Pre*	*Post*
Multiple methods	Transitional	Transitional
Multiple purposes	Transitional	Transitional
Justification	Informed	Informed
Data evidence	Transitional	Transitional

However, this was not in line with the researcher's observation. Therefore, we had a closer look on Dana's utterances to single questions in the VOSI illustrated here by two examples:

What types of activities do scientists (e.g., biologists, chemists, physicists, earth scientists) do to learn about the natural world? Discuss how scientists do their work.

<u>Dana's answer in pre-test (September)</u>

"They make graphics, inquire, read something about the things they want to explain further. They write down everything they know and try to draw conclusions."

<u>Dana's answer in post-test (following June)</u>

*"They **observe**, **analyze** with the **data they collected** and they inquire. They describe / explain it, draw conclusions and **give reasons** for the results."*

Both answers were coded on a transitional level with the category multiple methods. The coding rule[2] to apply this category is that two methods are mentioned at minimum without further explanation. This is given in both statements (pre and post). However, as highlighted in the answer above Dana uses much more scientifically appropriate vocabulary in the post-test. This is not captured by the category system.

The second example also shows a development into a more mature view on scientific inquiry although the answers could not be coded. There is no category matching Dana's answer.

Do you consider this person's investigation[3] to be scientific? Explain your answer.

<u>Dana's answer in pre-test (September)</u>

"Not really, because the beak of the birds is adapted to the way of living and eating behavior. […] That's logic thinking."

<u>Dana's answer in post-test (following June)</u>

"No, this person could easily figure that out if he/she would investigate thoroughly because that is not a novelty."

To sum up, Dana shows a very good academic performance in the laboratory which she estimates appropriately according to the self-concept test. From time to time she seems to be bored or unchallenged which is compensated with systemically inappropriate behavior.

Interesting to see is how the teachers react to the diversity in the classroom and to individual students (ad research question 2, see table 2). With Dana the teachers decided to treat her as very mature. Instead of admonishing her for being inattentive they leave her alone in these moments and try to encourage her or reinforce her when she gets involved in a task.

Furthermore, the teachers deliberately decide which inquiry level is appropriate according to the skills of the students (see table 1). At the end of the school year some students could work on their own research questions (open inquiry) while others received more support and input so that for them the task could not be classified as an open inquiry but as guided inquiry. Additionally, the teachers feel responsible for enhancing language skills also in science classes and try to consider the language level of the students in their tasks. They vary the length of sentences and words, the difficulty of vocabulary and they use appropriate grammar structures. They also try to increase language abilities by applying certain exercises when they realize difficulties. For example, the students had to practice the differences between difficult and heavy which sound very similar in German (schwierig vs. schwer) and the difference between to solve and to melt. The exercises are visualized very often (figure 2):

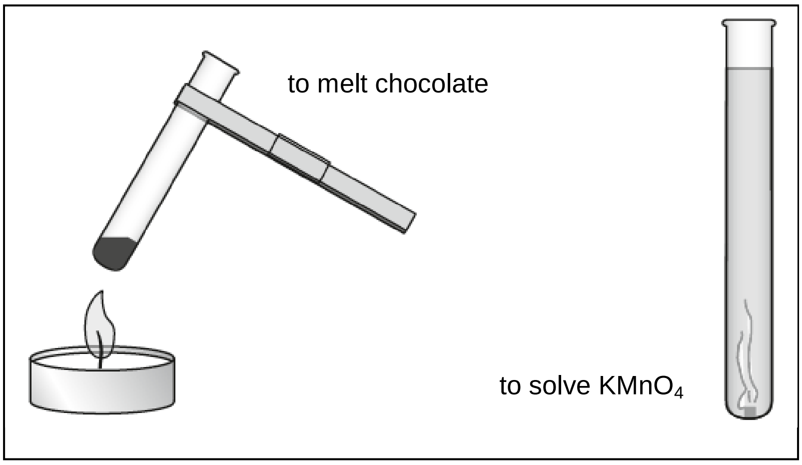

Figure 2. Visualization of an exercise

IMPLICATIONS AND CONCLUSIONS

The study has certain limitations. The most important to be named is the low number of students with whom the questionnaires were conducted. Nevertheless, the variation of the answers in all questionnaires used shows how important it is to look closer at the results qualitatively if possible and on an individual level. Sometimes the test results even hindered us to see the individual development and the strengths of each student.

We conclude that in highly diverse classrooms results of standardized instruments should be treated with even more caution. It has to be considered that the high diversity does not only impact teaching practices but also education research approaches. This study could be a contribution to reduce the gap between research and practice as the teachers in our case can use our thick descriptions of the students pre-conditions to adapt and reflect their teaching practices.

NOTES

1. Name was changed.

2. The coding rules were created by the second author to achieve a selective category system.

3. The investigation is about the connection of birds eating certain food and the shape of their beaks.

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