DEVELOPMENT OF AN INCLUSIVE, DIGITAL MEDIA-SUPPORTED LEARNING ENVIRONMENT FOR INQUIRY-BASED LEARNING

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Inquiry-based learning (IBL) is one possible teaching approach used to develop competences in three aspects: doing science, understanding scientific knowledge acquisition, and learning scientific content. Various studies show that IBL is successful under certain conditions, like proper scaffolding and teachers' reasonable understanding of scientific knowledge acquisition. Our project aims to support the implementation of IBL by supporting teachers and students alike. It offers additional digital scaffolding via a mobile website for students while they are participating in real-life experiments in the classroom. To develop digital support, in a first step teaching materials on inquiry-level 1 and 2 on the topic "chemical reactions" are implemented in two different urban schools in the eighth and ninth grade. Analysis of the gathered data (audio-recordings and the laboratory journals) helps in detecting areas for scaffolding. A digital environment providing scaffolding for the analysed areas is developed and assessed in an eighth grade of an urban secondary school. This paper shows the development from the first analogue inquiry box to the revised second inquiry box.

Keywords: scaffolding, multimedia and hypermedia learning, inquiry-based teaching

INTRODUCTION AND THEORETICAL BACKGROUND

Inquiry-based learning (IBL) is considered an important part of laboratory practice and it can contribute to gaining manifold competences in the field of doing inquiry, knowledge about inquiry and its connection to acquiring scientific content (Abrams, Southerland, & Evans, 2008). Nevertheless, it is not widespread, which is certainly because it is not easy to implement (Blanchard et al., 2010). Many national Science Education Standards and the curricula demand an implementation of inquiry-based science education. However, for example in Austria, only one in four teachers applies inquiry-based learning in regular lessons (Hofer, Lembens, & Abels, 2016). Therefore, the main aim of this project is to increase the use of inquiry-based learning by supporting teachers. Amongst the common reasons teachers give for a poor implementation of IBL are the high requirements for both teachers and students. In addition, there are several other potential areas of difficulty when implementing IBL. Two of the most-frequently mentioned pitfalls are a lack of scaffolding (cp. Blanchard et al., 2010; Kirschner, Sweller, & Clark, 2006; Mostafa, 2018) and the lack of meta-skills in doing inquiry (Blanchard et al., 2010; Lustick, 2009).

Our project (www.inquirysteps.com) aims to tackle both of the aforementioned pitfalls by introducing a digital media-supported learning environment to support teachers and students alike in inquiry-based lessons. In IBL, individual support for students – especially considering the high diversity in the classroom – is a particular challenge. Here, our project offers the possibility of increased individual and problem-specific support with the help of a website. In addition to the task-specific information, information about scientific inquiry and about scientific knowledge acquisition are provided. In other words, hypermedia provides multifaceted access to information (Arnold, Kilian, Thillosen, & Zimmer, 2018). However, the blended learning environment is what makes this project special, as it combines real-life hands-on experiments with digital scaffolding, supplemented with real-life scaffolding by the teacher.

Scaffolding should be provided in a way so that every student can learn within the "zone of proximal development" (Vygotsky, 1978). In diverse classrooms, the learning of all students has to be supported so the high as well as the low achievers should be actively addressed (Sliwka, 2010). Scaffolding is multidimensional and it may be divided into macro-scaffolding (planned in advance) and micro-scaffolding (ad-hoc scaffolding) (Hammond & Gibbons, 2005). The project focusses on macro-scaffolding which encompasses the tasks and all information and aids prepared to support the activities of the students. This will be applied to hands-on teaching material for inquiry-based learning at level 1 and 2 (Blanchard et al., 2010). Table 1 shows the responsibilities of the teachers and the students for each level.

Table 1: Levels of Inquiry (Blanchard et al., 2010)

	Source of the question	Data collection methods	Interpretation of the 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**

On level 1, the teacher provides the question as well as the method to gather data. Only the interpretation of the results is left to the students, whereas on level 2, the teacher only provides the question to be answered. The method and the interpretation are open to the students.

Other aspects of the scaffolding that needs to be provided include language, easy access, structure and navigation of the supporting website.

METHOD

In a previous project, a unit concerning the topic "chemical reaction" without digital support was designed and tested with middle-school students. The tasks and instructions of the unit can be assigned to Level 1. As a first step in the project, the tasks were formulated and expanded to enable IBL at level 2. In addition, it was important to adequately formulate the tasks for a diverse group of students.

This enhanced learning unit was tested by students of the 8th and 9th grade to detect learning difficulties and to research possible supporting mechanisms to overcome the pitfalls mentioned in the introduction. The unit was still analogue. The analysis was guided by the following research questions: Which scaffolding measures do they already use? What obstacles do the students encounter? What do the students need additionally? These questions were formulated against the background that the hurdles and needs are identified before digital implementation.

The timeline of our project is shown in Table 2.

Table 2. Timetable of the research project

Date	Data sources	Collected Data, expected outcome

December 2018	Data collection 9th grade chemistry class, urban business school	Audio-recordings
February 2019	Data collection 8th grade, urban secondary school	Audio-recordings, laboratory journals
March – May 2019	Data analysis – extraction necessary scaffolding measures	Deductive analysis of the audio-recordings and the lab journal using the scaffolding categories (Puddu, 2017) supplemented by inductive categories (Temper, 2019)
May – June 2019	Realising of the digitalised scaffolding measures	
End of June 2019	Implementing of the new digitalised scaffolding Data collection 8th grade, urban secondary school	Audio-recordings, digital lab journal entries Analysis with deductive and inductive coding for further improvement of the digital scaffolding

The first inquiry box on the topic chemical reactions is shown in Figure 1 on the left side. It contained petri dishes, a flask, a spatula, a balloon, snap-on lid glasses containing the chemicals, etc.

Figure 1: Content of the first (on the left side) and the second inquiry box (on the right side).

The data was analysed by using qualitative content analysis (Kuckartz, 2014) using deductive scaffolding categories (Puddu, 2017) which were supplemented by inductive categories (Temper, 2019).

Using the results, the tasks were digitalised and the inquiry box updated. The second inquiry box is shown in Figure 1 on the right side. The required support was implemented digitally following the premises: Which parts of the required scaffolding can be digitally adopted? What additional scaffolding has to be implemented to make the setting as inclusive as possible? How can digital help be made available to students in the best possible way and at the right time? The website was tested with eight graders concerning usability, acceptance and comprehension.

RESULTS

The first inquiry box (see Figure 1 left) contained the following tasks: The first task addressed the wording of the German word "Stoff" which means substance or matter. In German, the same word is used for cloth or fabric, so the scientific use of the word is introduced. The second task is about the mixing of substances, especially about the mixing of watercolours. Subsequently, the leaners fulfil the third task in which different substances react. The fourth tasks contrasts mixing and a chemical reaction between substances to highlight the differences. Afterwards the development of gas is introduced as an additional example for a chemical reaction. Up to this step, the learners only work on level one tasks. The next one, "What has bubbled?" is a level 2 task where the students have to plan the research. Finally, the students have to answer questions if the mentioned processes are chemical reactions or not.

The students' answers were collected and analysed to detect possible improvements of the box.

Table **3** lists the processes and the answers the groups have given on the question "Is this a chemical reaction?".

Table 3: results of the first box

Process: (12 groups)	Yes, this is a chemical reaction:
Tearing paper	0/12
Gas formation in the effervescent tablet	7/12
Mixing of two substances	**7/12**
Inflating a balloon	1/12
Burning paper	0/12
Reaction of two substances	8/12
Breaking a glass ball	0/12
Mixing colors	**7/12**

The results show that the answers to two questions were problematic. The students stated that the mixing substances and mixing colours are chemical reactions. To gain an in-depth perspective and explain this outcome, we analysed the audio-recordings and the laboratory journals in this order.

Problem 1: Too long to wait

The title of the inquiry box is "chemical reactions", but the students have mastered two tasks before they experience the first chemical reaction. The expectations the box raised might have compromised the observations and the interpretations. Based on the results obtained from the analysis of the data, the digital version was different. The aim to contrast mixing and reaction was skipped in favour of concentrating on chemical reactions.

Problem 2: Too many devices

One problem might be the overwhelming number of things in the first inquiry box. The students had difficulties with finding the necessary things in due time. Therefore, an additional game was introduced in the digitised version, in which the students had to assign pictures and names of the laboratory equipment, as shown in Figure 2. Those difficulties might have distracted the students from the learning goal.

Figure 2: Game: „laboratory equipment“

Problem 3: Too much to read

The analysis of the audio-recordings showed that the students did not read the manual and skipped the explanations. Some groups even mentioned that in the discussion. Sentences like “We should have read everything first.” were found repeatedly in the data. As a consequence, for the digital version, videos were made instead of written explanations. In the videos, the students can hear and see what to prepare for the next experiment. At important positions, as after preparing the required materials, the video would stop and the students have to press a button to continue with the video.

The revised inquiry box

The revised inquiry box (see Figure 1) contained less equipment and the tasks differed a bit. The first task was the game “laboratory equipment” followed by the task about the wording substance/matter. After that, two chemical reactions were made by the students, identified by colour changing. The next task offered the development of gas as an example of a chemical reaction. The level 2 task “What has bubbled?” remained the same. The last task again comprised the questions about chemical reactions.

The design of the website for this revised box complies with current guidelines (cp. Arnold et al., 2018; Golser, 2019; Mair, 2005). We wanted the website to be easy to use, so a clear navigation and colouring was needed. It has to be easy to read with adjustable font size, left justified. We used short sentences und few technical terms. Many instructions were adapted and supported by videos and pictures.

The following table (Table 4) shows the results of the last task of the inquiry box where the students read about different processes and they have to answer the question “Is this a chemical reaction?”.

Table 4: Results of the second box in comparison to the first box

Process: (10 groups)	Yes, this is a chemical reaction:	Yes: original box
Tearing paper	0/10	0/12
Gas formation in the effervescent tablet	8/10	7/12
Inflating a balloon with the mouth	1/10	1/12
Burning paper	4/10	0/12
Reaction of two substances to a new substance	10/10	8/12
Breaking a glass ball	0/10	0/12

Mixing of watercolours	0/10	7/12

The answers collected in the last task of the revised box suggest that the new structure was more effective (see Table 4). Most of the answers were correct, except the burning paper. Only four out of ten groups recognized this process as a chemical reaction. The reason is unclear and subject of further investigation.

OUTLOOK

The first step was to create a website, which is working for the students for their first steps in inquiry-based learning and is also be easy to use for teachers so they implement the inquiry box into their teaching. To be able to provide more inquiry boxes a new, professional website was programmed which included more scaffolding and support possibilities. With this new website, systematic research is needed to find out whether learning with inquiry boxes is effective. For this purpose, qualitative as well as quantitative methods are used.

REFERENCES

Abrams, E., Southerland, S. A., & Evans, C. (2008). Inquiry in the Classroom: Identifying Necessary Components of a Useful Definition. In E. Abrams, S. A. Southerland, & P. Silva (Eds.), *Inquiry in the Classroom: Realities and Opportunities* (pp. xi-xlii). Charlotte, North Carolina: Information Age Publishing.

Arnold, P., Kilian, L., Thillosen, A., & Zimmer, G. (2018). *Handbuch E-Learning [Handbook E-Learning]*. Bielefeld: Bertelsmann Verlag.

Blanchard, M. R., Southerland, S. A., Osborne, J. W., Sampson, V. D., Annetta, L. A., & Granger, E. M. (2010). Is Inquiry Possible in Light of Accountability?: A Quantitative Comparison of the Relative Effectiveness of Guided Inquiry and Verification Laboratory Instruction. *Science Education, 94*(4), 577-616.

Golser, L. S. (2019). *Die digitale Umsetzung einer Lernbegleitung im Rahmen des Projekts "INQUIRYsteps" am Beispiel eines Versuchs der Lernschachtel "chemische Reaktionen".* (BEd Bachelor thesis), University of Vienna, Vienna.

Hofer, E., Lembens, A., & Abels, S. (2016). Enquiry-based science education in austrian teacher professional development courses. In I. Eilks & B. Ralle (Eds.), *Science education research and practical work* (pp. 271-277). Aachen, Germany: Shaker.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist, 41*(2), 75-86.

Kuckartz, U. (2014). *Qualitative Inhaltsanalyse. Methoden, Praxis, Computerunterstützung [Qualitative Content Analysis. Methods, Practice and Computer Assistence]*. 2. überarbeitete Auflage: Beltz Juventa.

Lustick, D. (2009). The Failure of Inquiry: Preparing Science Teachers with an Authentic Investigation. *Journal of Science Teacher Education, 20*(6), 583-604.

Mair, D. (2005). *E-Learning - das Drehbuch: Handbuch für Medienautoren und Projektleiter*. Berlin: Springer.

Mostafa, T. (2018). How do science teachers teach science - and does it matter? doi:https://doi.org/10.1787/f3ac3fd6-en

Puddu, S. (2017). *Implementing Inquiry-based Learning in a Diverse Classroom: Investigating Strategies of Scaffolding and Students' Views of Scientific Inquiry* (Vol. 247). Berlin: Logos.

Temper, L. (2019). *Weiterentwicklung und Evaluation von Materialien zum Thema „Chemische Reaktionen“ im Projekt Inquiry Steps [Further development and evaluation of tasks concerning the topic "chemical reaction" within the project Inquiry Steps]*. (Magister Diplomarbeit), Universität Wien, Wien.