

Using Video Documentation in Out-Of-School Lab Days as an ICT Learning and Diagnostic Tool

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Abstract The use of ICT in science education offers many opportunities to promote students' learning and experimenting comprehensively. Considering that, it is important not simply to replace traditional media, but to explicitly identify the added value of ICT tools for students and teachers. Especially alternative forms of documenting experiments, particularly video documentation, provide both the possibility to diagnose students' individual learning conditions, abilities and difficulties as well as the opportunity to cope with students' cognitive and epistemological conceptions adequately. Apart from the school context, extracurricular activities (informal learning-settings, like out-of-school lab-days) can be used to explore the potential of video documentations. The following paper presents the use of video documentation as an ICT learning and diagnostic tool in the out-of-school lab "ELKE". Based on a qualitative examination, the video documentations give insight into students' professional and formal strengths and weaknesses - an added value that a traditional experiment protocol is not able to provide in this way.

Keywords: *ICT, video documentation of experiments, out-of-school lab days, diagnostic tool*

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1. Introduction

It is unanimous that out-of-school labs are of fundamental educational value as they enrich the students' usual learning environment in chemistry classes [1,2,3,4]. Through their pragmatic character, these out-of-school labs offer an activity-oriented approach, especially in the domain of natural sciences. Thus, students' scientific literacy develops when they are enabled to apply their acquired knowledge in different contexts. Students' diversity should be highly considered - comparable to common lessons - in order to induce learning processes successfully. The use of varied ICT tools and forms of experimentation is one possibility to offset students' diversity and, subsequently, to enrich their learning [5,6,7,8].

In addition, ICT tools as alternative forms of documenting experiments (e.g. videos, or podcasts) provide both, great potential for differentiation for heterogeneous learning groups and a diagnostic tool for teachers [8,9,10].

2. Out-Of-School Lab Days - the Concept of "ELKE"

Out-of-school labs provide unique opportunities to effectively link the university teacher education

system with the idea of competence-oriented chemistry teaching.

Thus, the extracurricular learning setting "ELKE" located in Cologne and Vienna can be described as a classical student laboratory and a teaching/learning lab for pre-service chemistry teachers at the same time [11]. The German acronym "ELKE" stands for experimenting (German: "Experimentieren"), learning (German: "Lernen") and acquiring competences (German: "Kompetenzen Erwerben") [12].

By means of the acronym "ELKE" the conception of the out-of-school lab can be further explained. As a student laboratory, "ELKE" offers a student-centred and competence-oriented design and aims at increasing the scientific interest and curiosity of the students involved in this program. The participants dispute about the planning, the conduction and the reflexion of experiments following up curricular content. Each "ELKE" experimentation day focuses on situational context, in order to constructively interrelate concept- and process-oriented competences. Both, the specific content and the didactic-methodical design of learning and experimentation may be, within "ELKE", adapted to the different preconditions of students' learning and development. In this regard, different topics offer a great variety of learning situations: individual and cooperative working phases are productively and meaningfully mixed and varied by different grades of autonomy for experimentation.

As a teaching/learning lab “ELKE” offers pre-service chemistry or other science teachers the opportunity to develop, reflect on, and improve their scientific and didactic expertise. The pre-service teachers manage and direct the student lab and supervise the small groups. In advance, they are qualified within correspondent university seminars to acquire necessary basic competences, like negotiation or classroom management skills. On the basis of video feedback, their experiences are discussed and reflected. Pre-service teachers are thus enabled to find their teaching role within a familiar but authentic atmosphere in front of a small number of students and without pressure to perform like in a formal school environment.

2.1. “ELKE” - Student Reporter in Lab

Within the framework of the student rather teaching/learning lab “ELKE” different experimentation days with emphasis on several topics may be provided [12]. Chemistry teachers can choose from a given range of topics and attend this experimentation day with their students for half a day.

Student Reporter in Lab is an experimentation day designed for students just starting with their chemistry lessons in school. The aim of *Student Reporter in Lab* is to provide deeper insight - in addition to their school lessons - into the topics of material properties, mixtures and separation processes. Methodically, this experimentation day is designed like a learning circuit with the purpose to achieve autonomous, individual and successful learning [13].

The experimentation day is embedded in the greater context of journalism. Thus, at the beginning of the experimentation day, the participating students are confronted with a fictional internet page with scientific questions of daily life, posed by other students. By means of autonomously conducted experiments during a carousel activity, the students are then asked to find answers and solutions to these questions.

Students set a detailed laboratory journal (“reporter script”) as a tool for structuring and contentual support for their experiments in the labs. Additionally, the supervising pre-service teachers assist several small groups of students, each group consisting of two to three students, during the execution and evaluation of the experiments. According to their work pace, the students run through an individual amount of activities and record each in their reporter scripts.

The final phase of this experimental circuit is the meeting of students and pre-service teachers in order to answer the questions based on the recent increased knowledge due to their experiences in the lab. Therefore, students choose between different types of documentation (video, or podcast). In a finishing editorial meeting, the students present their videos or podcasts.

The experimentation day is, particularly characterized by its emphasis on forms of documentation, highly motivating and differentiating. By means of common digital media, like smartphones and tablet-PCs, the conducted experiments can be profoundly understood and reflected. In order to be able to profit from the lab day and revisit the topics dealt with in class, the students’ digital works are saved on USB thumb drive and are handed out to the chemistry teachers.

2.2. The Potential of Digital Media for the Documentation of Experiments

A recent meta-analysis of large-scale datasets by Liao & Lai [14] shows - for assessing the impact of information and communication technology in education - higher effect sizes for students’ learning performance (cognitive, affective, and social skills) when students are learning with digital technologies than without digital technologies. In order to foster teaching and learning adequately, it is important to consider the context in which ICT tools and applications are used [15].

In the context of science education, ICT is widely used for visualizations like computerized molecular modelling or animations, for collecting and analysing data as well as for designing learning environments [16].

Another, yet less widely used approach, is the use of video documentation of an experiment. It has the potential to replace the traditional experiment protocol and simultaneously to foster students’ understanding and reflection of the experiments conducted.

Employing video as a diagnostic tool, teachers gain more in-depth insight into the learning process of students who are mostly experimenting autonomously and self-reliant.

2.2.1. The Potential of Video Documentation for Students

Especially the use of video documentation for students conducting experiments themselves, offers the opportunity to present moving pictures, to use professional language for describing and explaining the proceedings. Video documentation is a tool of differentiation as it supports especially students having difficulties in textualization. Although the focus is always on the experiment, a video is able to record the observations of more passive students, their social interactions, their emotions and affective attitudes (see 3.2. *person-related video documentation*). Thus, the recording of a video documentation can be regarded as a didactic tool to foster cooperative behaviour since social and affective skills are demanded and become obvious. The classic result-oriented experiment protocol often tends to be presented in a generalized form and as a consequence, but regularly neglects the individual learning preconditions and preferences of each student.

Compared to traditional analogue experiment protocols, video documentations (and podcasts) present the result of the conducted experiment, its context and the entire process of experimentation all at once.

Moreover, due to the use of digital media, particularly the smartphone, students are highly motivated as there is a connection to their everyday life. After all, smartphones are the most widely used media tool nowadays (JIM study, [17]). Through video documentation, the experiment is not reduced to its rational logical findings; moreover, it is the student and his/her activity that is mainly focused on.

Compared to classic experiment protocols, focusing on the result-oriented approach, video documentation allows a process-oriented deeper reflection of the conducted experiment. The recording of a video documentation requires extensive examination of the subject-specific content. Students combine subject-specific linguistic usage with moving pictures and use this synergy to stress important content issues.

Another advantage is the fact that students using their own smartphones, are able to watch the video any time to consolidate their findings (learning by revision). Working with a self-made video means that students may return to substantial and significant phases of the experiment with the aim to analyse principal processes thoroughly and to establish causal coherences. This process may lead to new subject-specific and methodical understanding [10]. Through their active role in the documentation process, students are encouraged to recognize and to reflect the distinct course of action when conducting an experiment (e.g. [18]), consequently they have the chance to fully immerse into the subject-specific content of the experiment, to broaden their chemical understanding and to consolidate their acquired knowledge.

A challenge for the students can be the appropriate technical handling, as this may generate an additional cognitive load [19]. To unfold the benefits of video documentation, the teacher needs to introduce the students adequately to the creation of such videos.

At the same time, it must be noted that it is not an effective form of documentation for every student. For the purpose of differentiation, various types of experimentation protocol should be used in a targeted manner for each student.

2.2.2. The Potential of Video Documentation for Teachers

To the same degree as video documentation serves as a differentiation tool for students, it is equally utilizable as a didactic tool of diagnosis for teachers. On the one hand, the use of video as an alternative type of documentation implies the opportunity for teachers to assess students' learning outcome. On the other hand, the use of videos allows teachers to diagnose students' strengths and weaknesses related to adequate documentation of experiments, such as their ability to experiment, their social competences as well as their attitudes towards the experiment and the way of documentation [9]. Video documentation provides both, insights in the students' gain of knowledge and in their individual learning progress.

Furthermore, with the help of the detailed video documentation, students profit from comprehensible evaluation and reflected feedback from their teachers. Thus, students are enabled to rank their performances and, if required, to modify them.

Recently, studies have given evidence that teachers' feedback is - with regard to the students' learning success - of utmost significance in their daily interaction (e.g. [20]). As videos are directly embedded in the course of the class, teachers are able to attend, to understand and to support their students' individuality. For the teachers, the technical handling and use of the devices can be a challenge, because the necessary competencies cannot be presupposed automatically (TPACK [21]).

Video documentation reports the students' cognitive abilities concerning the contentual and formal demands on documentation of experiments and offers diagnosis of the students use of subject-specific terminology, including linguistic and pragmatic presentation of any experiment design, its conduction, observation and its final summary with the respective interpretation. Compared to the classical protocol of an experiment, teachers additionally uncover with the help of the video students' psychomotor

performance while conducting the experiment [10]. The students hand control while preparing and conducting the experiment as well as their linguistic resume become immediately visible in this form of detailed documentation.

In summary, we can assert that with the help of videos teachers are enabled to holistically diagnose students' performances, learning strategies and conditions as well as their general prerequisites and attitudes. Consequently, video documentation represents a significant contribution towards chemistry classes with a focus on the students' individual needs, particularly in inclusive chemistry lesson, which are of increased importance nowadays (e.g. [22]).

3. The Use of Video Documentation within "ELKE" - Students Reporter in Lab

As described in Chapter 2.1, students take the role of reporters within the experimentation day *Student Reporter in Labs*. By means of the conducted experiments students are able to find answers to a scientific question of daily life and are forced to document their results using videos or podcasts. The questions originate from their living environment, e.g. "Why are the stones of the Cologne Cathedral regularly replaced?", "Why am I able to float on the Dead Sea's surface and not on the surface of a swimming pool?" or "Why does red cabbage sometimes look red and sometimes rather blue?"

After the practical stage, when students are capable of answering these questions professionally, they have to reflect how to present their results by means of a video or a podcast. In this phase there are no limitations to students' creativity except that their experiment has to be in the centre of their documentation. Students have the choice between a documentation that is either *issue-related* or *person-related*.

In the *issue-related documentation*, only the instruments used in the experiment are recorded, either via video or via audio description with a voice-off, whereas in the *person-related documentation* students are actively taped in front of the camera. In support of the design of their video, students receive a short video documentation guide and the opportunity to script essential notes (see Figure 1). This comprehensive preparation is needed for the video shoot in order to receive an effective medium of knowledge acquisition. In addition, students receive a box with materials they can use in the experiment as well as a tablet-PC for the video shooting, if needed (see Figure 2).

When assisting the video documentation, the mentoring pre-service teachers observe carefully that the phenomenological presentation and description of the experiment and the submicroscopic interpretation are included appropriately by the students. In comparison to the written interpretation in a classical experiment protocol, the oral interpretation necessary in a video documentation can be regarded as more challenging.

In the following, both types of video documentation are presented, the first one is *issue-related* whereas the other is *person-related*. Students had to find an answer to the question why the stones of the Cologne Cathedral have to be regularly renewed (see chapter 3.1 and 3.2). This task

demands knowledge transfer and relies on the students' technical knowledge concerning the material properties.

All personal data in the following is anonymized.

These screenshots show that the students' video includes the essential components of a documentation (see Figure 3 - Figure 9). After a short personal introduction, the students state the aim of their experiment first (see Figure 3) and explain its application in the given context (see Figure 4). The information on material and chemical products is given implicitly and figuratively, just by the chosen presentation of the experimental setup in front of the camera. The students then start their experimental procedure accompanied by their utterances and comments (see Figure 5, Figure 6, Figure 7). Subsequently, they accentuate their observations explicitly (Figure 8, "[...] I mean, the content of the tube, starts bubbling and that the calcium carbonate dissolves"). As these students has just started with elementary chemistry

instruction, their interpretation is formally, on the level of phenomenology, not separated from their observation but included. Finally, the students transfer their results into the context and answer the question from the beginning (see Figure 9).

In addition to the protocol-related aspects, the video gives insight into the students' experimental competences (their proper and reliable performance) and it shows that these students are able to experiment and to document in an organized, structured and concentrated way.

Regarding their social interactions, both students have agreed on their tasks before they started the video documentation. One takes the role of the experiment leader and the other one comments it. Both complement one another perfectly: the narrator comments - as the voice from off - on the experiment whereas the experiment leader is conducting the experiment.

"Student Reporter in lab"



Video Documentation Guide

- Shoot a *video* as UzK reporters, to find an answer to the given question!
- In advance, think carefully about the video design and consider the following points:
 - The focus of the video should be your answer to the question!
 - Your video should include an introduction, a main part and a conclusion at the end!
 - Every student should take part in the video!
 - Please note the particularities of a video shooting: You can express the issue not only linguistically, but also with the help of your gestures and your facial expressions.
- To be perfectly prepared for the shooting, please write a short script in advance.

Our screen-play:

Out-of-school lab ELKE



Figure 1. Video Documentation Guide



Figure 2. Experimental Box

3.1. The Issue-related Video Documentation

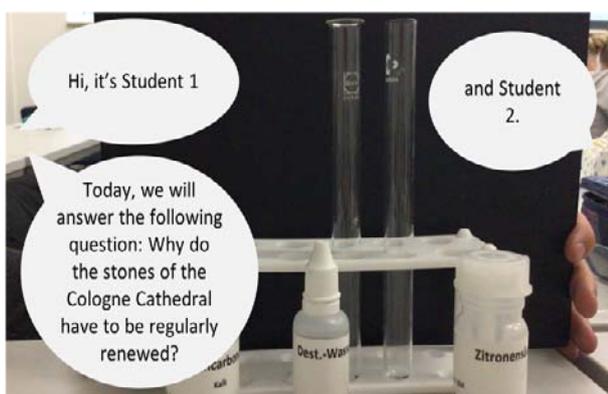


Figure 3. Snippet 1

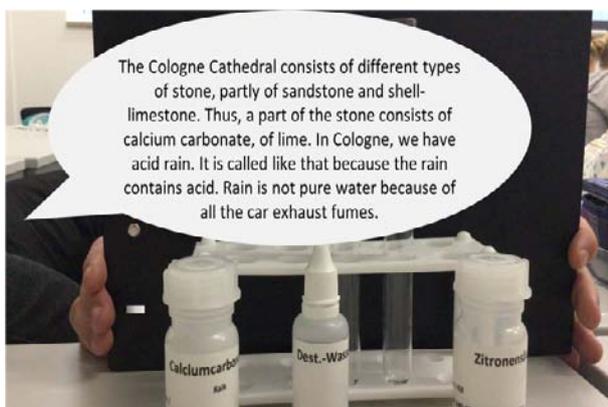


Figure 4. Snippet 2

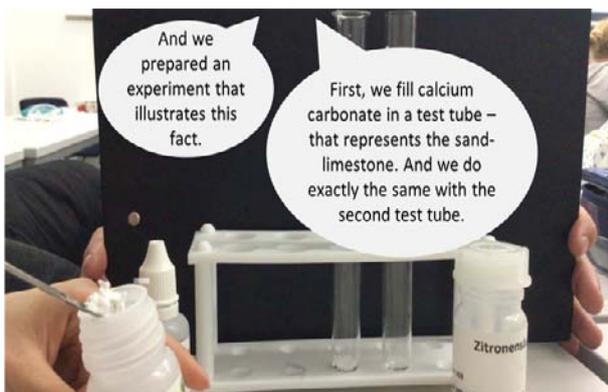


Figure 5. Snippet 3



Figure 6. Snippet 4



Figure 7. Snippet 5

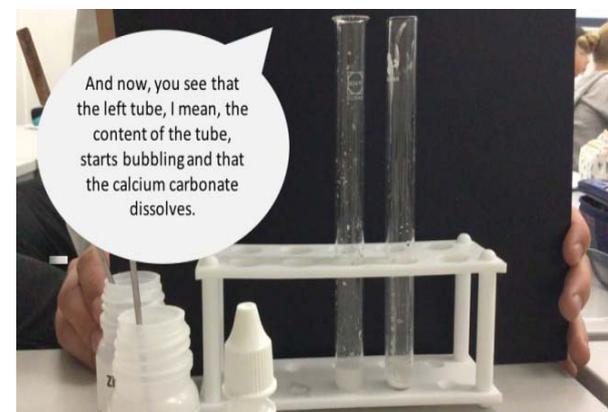


Figure 8. Snippet 6



Figure 9. Snippet 7

3.2. The Person-related Video Documentation



Figure 10. Snippet 1

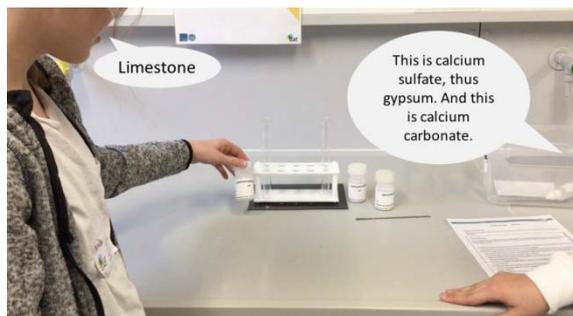


Figure 11. Snippet 2

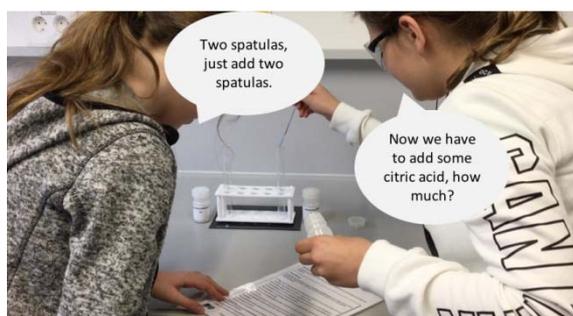


Figure 12. Snippet 3

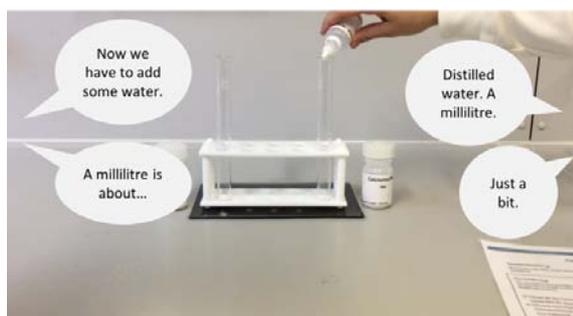


Figure 13. Snippet 4

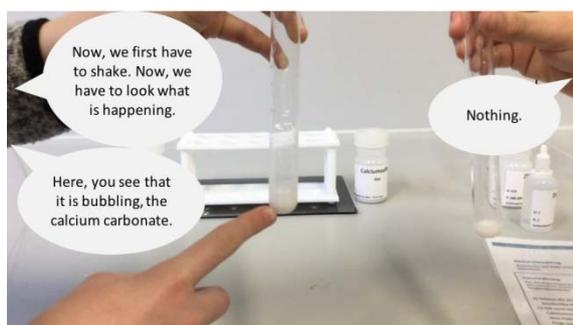


Figure 14. Snippet 5



Figure 15. Snippet 6

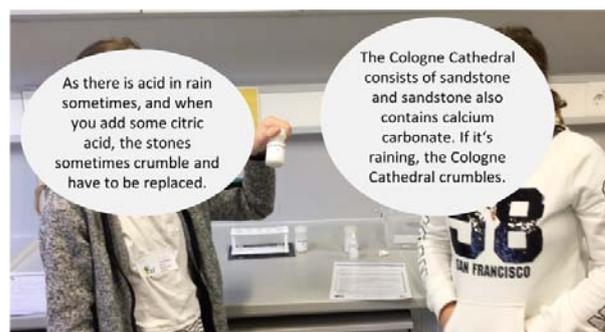


Figure 16. Snippet 7

In this *person-related video*, the students present the aim of their experiment and its embedding in the superordinate context (see Figure 10). Instead of presenting the needed material and chemicals in advance, both students name these when executing the experiment (Figure 11, Figure 12, Figure 13, e.g. "[...] And this is calcium carbonate", "lime", "two spatulas" [...]). They frame their observation as being an instruction (Figure 14, "Now, we have to look what is happening...") followed by a description of their observations. In this video, the students use calcium sulphate as an example of the building material gypsum to compare its reaction to limestone. One student does not register anything while the other student notes that, "it is bubbling, the calcium carbonate" (Figure 14). In the case of calcium sulphate, the students are not able to detect any bubbles (Figure 15). According to their prior knowledge, these students interpret the results of their observation just on a phenomenological level with the aim of answering the superordinate question (Figure 16). This video documentation is characterized by the close cooperation and mutual support of these two students: alternately, both undertake descriptive as well as experimental parts. In contrast to the *issue-related documentation*, the camera is directed by a third student who focuses on the experimenting students as well as on the experiment itself.

First, the camera angle is on the medium shot (Figure 10), then the camera setting is on head- and shoulder close-ups (Figure 11, Figure 12) before the video is shot in close-ups to illustrate the observations. (Figure 14). Finally, the camera angle is on the medium spot, like in the beginning (Figure 16). In addition to the protocol-related aspects, the students' experimental competences become obvious as well. Thus, this video documentation reveals the students' appropriate organization and their focused working-style when experimenting and documenting.

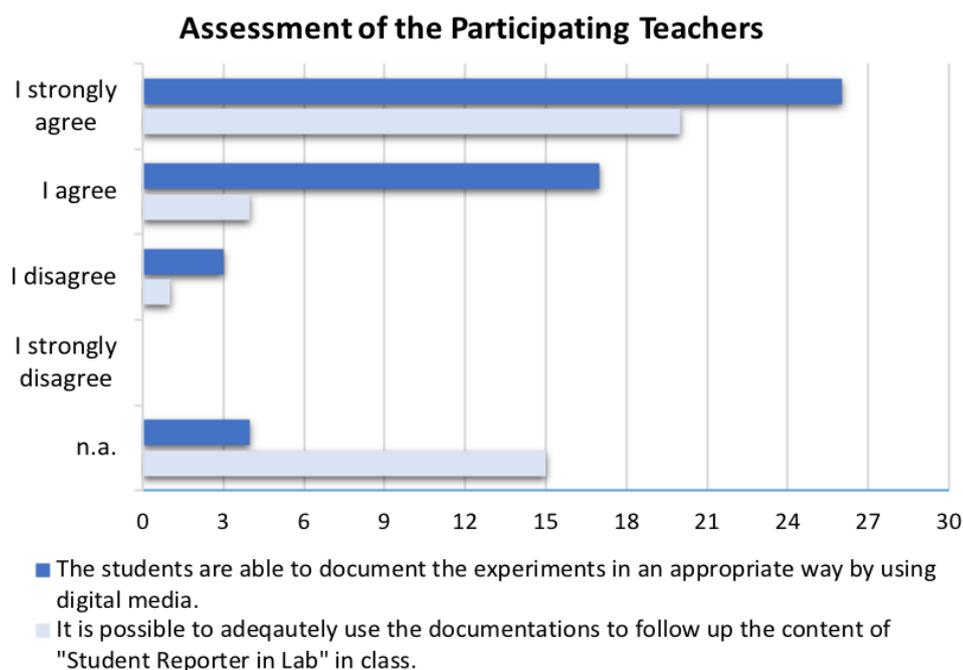


Figure 17. Excerpt of Teachers' Assessment

Both video documentations reveal many positive documentary aspects but also the challenges, the students have to struggle with. The video as a diagnostic tool gives some indication of the students' cognitive, psychometric and social skills the teaching person has to consider with regard to his further lessons (cf. chapter 4).

3.3. Teachers' Assessment of the Video Documentation

After its usage, the teachers involved were asked to estimate the value of a video documentation using a semi-structured questionnaire (see Figure 17, Table 1).

43 out of 50 teachers state that students are able to document the executed experiments appropriately using digital media. In addition, 34 teachers confirm that it is possible to use this type of documentation to revise the content in the following chemistry lessons (Figure 17).

The answers to the open questions underline the high potential of digital types of documentation for the overall promotion of various students' competences (see Table 1).

Table 1. Most frequently answers of teachers to the question: Which competences can be addressed by using digital documentation of an experiment?

Category	Number of responses
Ability to work in a team	19
Dealing with digital media adequately	10
Communicative skills	9
Social skills	7

Teachers clearly discern the added value of video documentation specially to promote the students' cooperative skills.

The joint shooting of a video protocol demands constructive cooperation and active communicative processes about subject content among the participating students. In order to achieve an adequate result, students are multiply

challenged: they need to exchange views on the subject content, they need to adjust their activities for a common objective and finally, they need to give mutual feedback and support in the sense of instructing one another (face-to-face interaction). Thus, video documentation can be seen as an in-depth examination of the subject content and the single stages of the experiment.

Nonetheless, the presented video documentations display the necessity to reflect the shot videos in class afterwards. Although teachers observed the acquisition of various practical and social competences employing digital media for documentation, there were no comments on the increase of content knowledge. Therefore, further studies are needed to analyze the growth of content knowledge through the use of ICT tools.

4. Summary and Outlook

The use of videos as alternative types of documentation of an experiment shows potential as an ICT learning and diagnostic tool.

Videos reveal the students' content knowledge as well as their practical and social strengths and deficiencies. Furthermore, they reveal the students' mastery of technical language explicitly, allowing to review any observable difficulties in class. Learning aids for technical language usage may be provided for slower learning groups. In both kinds of video documentation presented, the students' technical language usage is appropriate for their elementary level in chemistry instruction.

Nevertheless, the students' statements also display the need of educational support regarding to the adequate chemical evaluation of the experiment (e.g., "The Cologne Cathedral consists of sandstone and sandstone contains also calcium carbonate. If it's raining, the Cologne Cathedral crumbles", see Figure 16). Although the students are not yet introduced to the concept of the

chemical reaction, it is crucial for students to understand the basic idea of what happens in the experiments, namely that the citric acid dissolves with the calcium carbonate developing gas and transfer the results of the model experiment into the superordinate context. Ideally, they are able to build the bridge between the citric acid and the acid rain, which attacks the lime-sandstone of the Cologne Cathedral, which dissolves continuously. On this basis they conclude why the stones of the Cologne Cathedral have to be renewed regularly.

Indeed, in both videos the students confound the level of observation with the level of application on the given superordinate context repeatedly. In order to facilitate contentual learning, the levels of observation, interpretation and application on the superordinate context have to be discussed in class.

That way, video documentation offers the opportunity to promote communicative skills as students are encouraged to make use of the appropriate technical wording in chemistry. Furthermore, as manual and experimental competences are visible, the students' psychometric skills and abilities can be thoroughly observed and detected by teachers.

The video offers the revelation of correct and secure handling of chemicals and material. Additionally, teachers are able to state difficulties and challenges when conducting experiments and can give feedback on those constructively in class afterwards. Students' social interaction can be discussed comprehensively. The *issue-related video documentation* is characterized by a cooperative working style that relies on a distinct distribution of tasks: one student takes the experimental part and the other student comments on the different phases as an off-voice. A distinct distribution of tasks and roles is an essential and target-aimed strategy for heterogeneous learning groups if a cooperative working style is demanded [23]. In contrast, the example of the *person-related video documentation* reveals the students' cooperation regarding explanation and realisation of the experiment as well as their mutual support (e.g. "and the other," "nothing is happening in fact, it is just mixed", see Figure 6).

In summary, alternative types of documentation of experiments using ICT tools bear potential, which classic experiment protocols do not. The integration of these video documentations into the university education of prospective chemistry teachers allows them to gain hands-on experiences in the use of ICT tools and prepares them to design and teach innovative, high-quality chemistry lessons. Further studies must show how video documentations can be used to revise the student lab days in class reasonably and integrate them into further in-class use.

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