

Transferring and Optimizing a Laptop-based Learning Environment for the Use on iPads

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Received January 05, 2020; Revised February 14, 2020; Accepted March 05, 2020

Abstract With the growing presence of laptops, smartphones and tablets, daily life as well as professional needs are changing [1]. However, this means that mobile devices are playing an increasingly important role in schools and classrooms [2,3]. In particular, tablets are seen as a highly promising possibility to implement digital media in schools [4]. In this context, we would like to take a closer look at the use of tablets in initial chemistry classes. Therefore, we transferred a digital learning software, that had been developed for laptops, to iPads in order to optimize the learning environment through the possibilities offered by this latest innovation. This further development especially aims at the integration of experiments and a higher universal accessibility for learners in heterogeneous or inclusive learning groups. The aim of this project is to investigate the effect of the use of tablets in the following two teaching phases: During the input phase, the students work on the iPad-based learning environment. In the internalization phase, working with tablet-based tasks is compared with creating student explanatory videos regarding their impact on knowledge growth and attractiveness. In this paper, we focus the transfer of the laptop-based learning environment to iPads.

Keywords: computer based learning, tablet based learning, digitization, inclusion, universal accessibility

Cite This Article: Greitemann L., and Melle I., "Transferring and Optimizing a Laptop-based Learning Environment for the Use on iPads." *World Journal of Chemical Education*, vol. 8, no. 1 (2020): 40-46. doi: 10.12691/wjce-8-1-5.

1. Introduction

Since the ratification of the *UN Convention on the Rights of Persons with Disabilities* in Germany in 2009, people with disabilities have the right to equal participation in school life [5]. Overall, Germany has thus switched to an inclusive school system in which people with and without disabilities are taught together. As this goes hand in hand with an increasing heterogeneity in school classes, education has to consider this aspect accordingly. Hence, teachers have to adapt their teaching in such a way that each student - regardless of age, gender, origin, level of performance, etc. - is able to participate in the classroom. To reach this goal, the *Universal Design for Learning* (UDL), developed in the USA, shows possibilities for planning inclusive lessons [6].

With the continuing digitization in schools, the UDL provides even further and more various opportunities to approach the increasing heterogeneity in the classes since a digital learning environment for laptops or tablets offers the possibility of reducing barriers of learning [6,7] and thus enables universal accessibility. Furthermore, due to the high presence of digital media in the lives of students, digitization in schools is becoming more and more important. Hence, learning with, but also about digital media is also called for by the strategy paper "Education

in the Digital World" by the *Conference of Education Ministers* throughout Germany [8].

Considering these two developments, it is of interest to explore the use of digital learning environments more closely. In this context, we focus on the usage of a developed learning software on either laptops or tablets.

2. Theoretical Background

With regard to the learning environment, it is interesting to take a look at two major aspects: digitization and inclusion. Therefore, in this chapter, aspects of the digitization in schools will be discussed with a closer look at the use of laptops and tablets. Moreover, the UDL will be addressed, which makes it possible to plan universal accessible teaching materials for inclusive or heterogeneous learning groups.

2.1. Digitization

In the age of digitization, the use of mobile devices for learning and teaching is playing an ever-increasing role [2,3,4]. Thus, it is worth taking a closer look at the possible applications of digital media in the classroom - especially in regard to laptops and tablets.

The use of digital media (e.g. laptops or tablets) offers the advantage of teaching variedly and effectively, while

taking the different learning requirements of the students into account [9]. Among other things, digital technologies feature integrated functionalities that support learning processes. For example, the students can use mobile devices to have texts read aloud or enlarged [10,11]. This combination of auditory and visual information intake - which is made possible by digital technologies - can also help to reduce cognitive load [12]. Thus, part of the information can be processed in the visual system, while the other part is processed in the auditory system [12]. In general, digital media can be used to provide interactive materials [13]. With interactive learning content it is possible to address different sensory channels and convey it with dynamically representations, for example [13,14]. Digital media also have the advantage that they can be used for individualization and differentiation. For example, a teacher can provide a learning computer with which students can work at their own pace [12,15]. Furthermore, the use of digital media makes it possible to offer various ways of the information representation [13]. For example, within a digital learning environment, it is realizable to provide different text versions. These, in turn, allow students to decide which text to work with and thus helps them to achieve a higher degree of self-determination [13,14]. Furthermore, it is possible to provide various types of assistance in a digital learning environment. This individual assistance can either be obviously displayed on the device and thus directly offered or hidden and clicked on when it is really needed [13]. Another advantage of digital learning environments is the fact that digital media make it possible to use non-linear learning paths, which are not possible with analogue schoolbooks to this extent [13].

However, before using digital media in the classroom, the actual added value of digital media should be thoroughly assessed by the teacher [12]. Digital media offer suitable ways of illustrating phenomena, giving individual feedback to students on their performances and for evaluating teaching activities [12,16,17]. Furthermore, a meta-study found that the sole use of digital media in teaching is not as effective as the alternation of digital and analogue media. Thus, the complementary use of digital media and traditional teaching might be the best way [12].

In order to take a closer look at the benefits of digital media, it is worth considering their possible didactic functions in science teaching. Huwer and Brünken characterize the use of tablets in teaching by three different forms of usages: "tablet as a learning tool" (e.g. support of the learning process through visualizations), "tablet as a learning companion" (e.g. support of the learning process over a longer period of time) and "tablet as an experimental tool" (e.g. support of the experiments by direct measured value acquisition) [13,18]. The first two forms of applications cannot only be realized with tablets, but also with laptops. For example, digital learning environments can be used on laptops, which then serve both as a leaning tool and as a learning companion [19]. However, it is more difficult to use a laptop as an experimental tool, which is why tablets offer a greater advantage in this case. For example, this is due to the easy handling of the devices as well as the already integrated sensors and cameras. In the following,

we will therefore focus on the application form "tablet as an experimental tool".

This type of the use of tablets is of importance because experiments are an elementary component of science teaching [20,21]. While experimenting, tablets can be meaningfully used in the introduction, the performance and documentation of an experiment.

During the introduction to an experiment, the tablet has a motivating function. For example, problems can be easily presented in form of videos or comics. The videos or comics may be created by the teachers themselves using the digital devices [22,23]. Moreover, video instructions and/or animations can be used to explain the course of the experiment to the learners and it is also possible to visualize the applied materials on the tablets with pictures for additional support [22,23,24].

For conducting an experiment, virtual labs, video demonstrations or simulations may be used. If the students carry out the experiment practically, however, mobile devices such as tablets offer, for example, the possibility of digital data collection. Due to many built-in sensors (e.g., light intensity sensor) in the tablets, digital measured values can be recorded directly and graphically prepared [22,23,25,26,27,28]. It is also possible to connect external sensors to the tablet, which allows collecting and analyzing the data of these sensors digitally.

A great advantage of tablets for documenting the results of an experiment is the photo function. This makes it possible to document an experiment, e. g. in form of a before/after comparison. For some students, this is easier than writing down their observations. Furthermore, the devices offer the possibility of audio documentation, e.g. by recording the experimental protocol through the built-in microphone. This is particularly helpful for learners with difficulties not only in writing but also in spelling. The photo or audio documentations can also be seen as differentiated learning aids that support students on their way to an adequate experimental protocol [29]. Experimental phenomena can also be slowed down by the slow-motion function or presented faster through the time-lapse function [30,31,32,33].

In summary, both, laptops and tablets offer several advantages in science teaching. Tablets, however, offer an even wider range of application possibilities than laptops. Moreover, the handling is more comfortable.

2.2. Universal Accessibility

As already mentioned, the German school system demands the equal participation of all students in school lessons [5]. However, even today the lessons are often still planned for an imaginary average student [34]. As a result, teachers often neither perceive nor address the prevailing heterogeneity of students in the lesson planning and offer only one access to learning for all students. For some learners this access poses various barriers. In order to overcome these barriers, students need additional support, for example from the teacher.

Based on this, some teachers demand lessons that are individually tailored to the needs of their students. One way to achieve this is to provide a learning environment with universal accessibility, which offers various ways for

each student to gain an individual access to learning. The *Universal Design for Learning* (UDL) addresses this issue and offers a framework for planning a lesson with universal accessibility [6].

The UDL uses three principles based on findings of educational research. Each of these principles is subdivided into three guidelines, whereby these guidelines, in turn, are further broken down into checkpoints. These guidelines and checkpoints elaborate the three principles. The table in Figure 1 gives an overview of the UDL. For reasons of clarity, the checkpoints in Figure 1 are omitted. Hence, only the three principles and the nine guidelines are shown. The checkpoints can be found on the homepage of CAST [6].

In general, the UDL includes measures for *engagement*, *representation* as well as *action and expression*. In this context, teaching according to the principles of the UDL offers a high degree of flexibility and variability, so that ideally all unnecessary barriers can be minimized. This allows as many students as possible to actively participate in the lessons. The UDL is considered as a scientifically valid concept [35] but can hardly be explored as a complete concept, since the demand for flexibility and variability in teaching makes research difficult [36]. However, the individual aspects of the UDL have been validated [36].

Principles		Provide multiple means of Engagement	Provide multiple means of Representation	Provide multiple means of Action & Expression
Guidelines	Access	1. Recruiting Interest	4. Perception	7. Physical Action
	Build	2. Sustaining Effort & Persistence	5. Language & Symbols	8. Expression & Communication
	Internalize	3. Self Regulation	6. Comprehension	9. Executive Functions
Goals		Purposeful & Motivated	Resourceful & Knowledgeable	Strategic & Goal Directed

Figure 1. Summarized Table of the UDL (cf. [6,19,37])

Relating to the continuing digitization in schools, the UDL provides further and more various opportunities to approach the increasing heterogeneity in the classes as digital media offer more possibilities of differentiation and individualization than analogue media. For example, based on their adaptivity and flexibility, digital learning environments offer the potential for differentiation and can thus encourage students' active engagement with a specific topic [38]. In addition, learning with digital media allows multi-channel learning and therefore supports the retention of information, while also supporting students individually, e.g. by helping them to read, write and solve tasks [39,40,41]. However, the use of digital media in teaching does not yet result in the implementation of all UDL guidelines [6,42]. Nevertheless, the use of digital media in teaching makes it easier to minimize barriers in learning [6,7].

3. The Learning Software

In the following, we focus on an iPad-based learning environment which bases on a learning software for the

use on laptops. The laptop-based learning software was only used as a learning tool. With the transfer of this learning software for the use on iPads, it was possible to use it as both, a learning tool and an experimental tool.

The laptop-based learning software, which was, in turn, developed on the basis of analogue teaching materials, has already been developed and evaluated within a predecessor project in our research group [19,43]. For our subsequent developing process we used an authoring software called *Mediator 9.0* [44] to create an interactive learning software. Given that we were working with a digital authoring software, it was possible to make use of the potential of digital tools and to implement more aspects of the UDL in the learning environment, for example, through audio recordings or videos.

The laptop-based learning software deals with the introduction of the basic concept of chemical reactions for the initial tuition in chemistry. Figure 2 shows the structure of the learning software.

The learning software consists of two parts, each of them designed for a 90 minute-lesson. The first part deals with the topics *Chemical Reaction*, *Chemical equation* and *Physical process*, whereas the second part contains the topics *Oxidation*, *Constancy of mass* and *Submicroscopic level*. Each of these six chapters is divided into an information input and a self-assessment phase, followed by various tasks. Before the students can move on to the next chapter, they have to complete all three parts of a chapter. This is an important configuration of the software since the individual thematic areas build on each other. Both parts of the learning software are linked by a 45-minute experimental phase, which is carried out with analogue materials of a predecessor project [43].

In the laptop-based learning software we implemented many aspects of the UDL in both, the analogue materials for the experimental phase and the digital learning software, as each of the nine guidelines was always considered by at least one aspect. These include, for example, the use of easy language (guidelines 4 and 5), the use of feedback and sample solutions for the tasks (guidelines 2 and 8) or iconic and pictographic support (guideline 5).

Baumann and Melle evaluated the developed laptop-based learning software with both, students without special educational needs and students with special educational needs. Both student groups were able to significantly increase their chemistry knowledge through the learning software. The students with special educational needs achieve lower scores than the students without special educational needs in the pre-tests and the post-tests. Moreover, the learning software is perceived as very attractive by both groups. In terms of attractiveness, no significant differences could be observed between the two groups of students [19].

As part of the further development and optimization of the learning software, it was modified for the use on iPads. By using tablets, it was possible to implement some improvements - also with regard to the UDL. In the course of this, the last two chapters (*Constancy of mass*, *Submicroscopic level*) have been omitted for reasons of time, which is why the learning environment now consists of the four chapters *Chemical reaction*, *Chemical equation*, *Physical process* and *Oxidation*. This was complemented

by the fifth chapter *Experiments* and an introductory chapter on the use of the digital learning environment (see Figure 3). The experimental phase is followed by an internalization phase, which should consolidate both, the contents of the information input and the practical phase: One half of the students work on tasks relating to the previous chapters, while the other half creates their own explanatory video in order to consolidate the content learnt. The division of students into these two groups bases on the pre-test results (prior knowledge and cognitive skills). The aim of this parallelization is to ensure that both groups have the same prerequisites. This is important in order to compare the two internalization methods, because we would like to find out how effective and practical these two methods are. For this reason, the students were not

given the choice between the two methods. Due to the scope of this paper, the focus is on the information input and the experimental phase and not on the internalization phase.

The digital realization of the learning environment for iPads was done with the program *iBooks Author* [45] with which we created an interactive *iBook*. On the one hand, the program *iBooks Author* offers internal functions, which are already provided by the program itself. These are called widgets and allow the integration of diverse functions in the *iBook*, for example taking a photo. On the other hand, it is also possible to integrate external html-based widgets. By using iPads, the students have the possibility to write with the integrated keyboard of the devices. In addition, students can also use the *Apple Pencil* to make handwritten drawings and/or write a text.

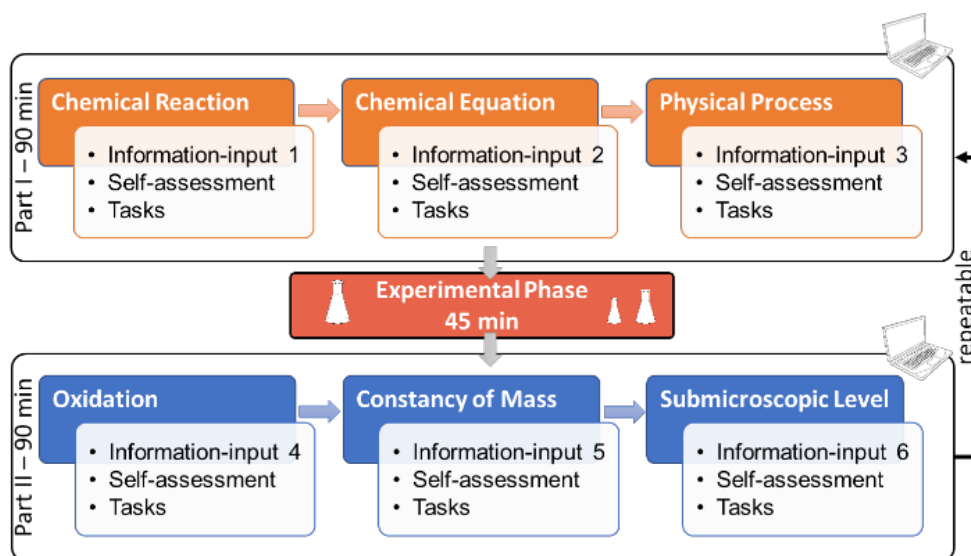


Figure 2. Structure of the Laptop-based Learning Software (cf. [19])

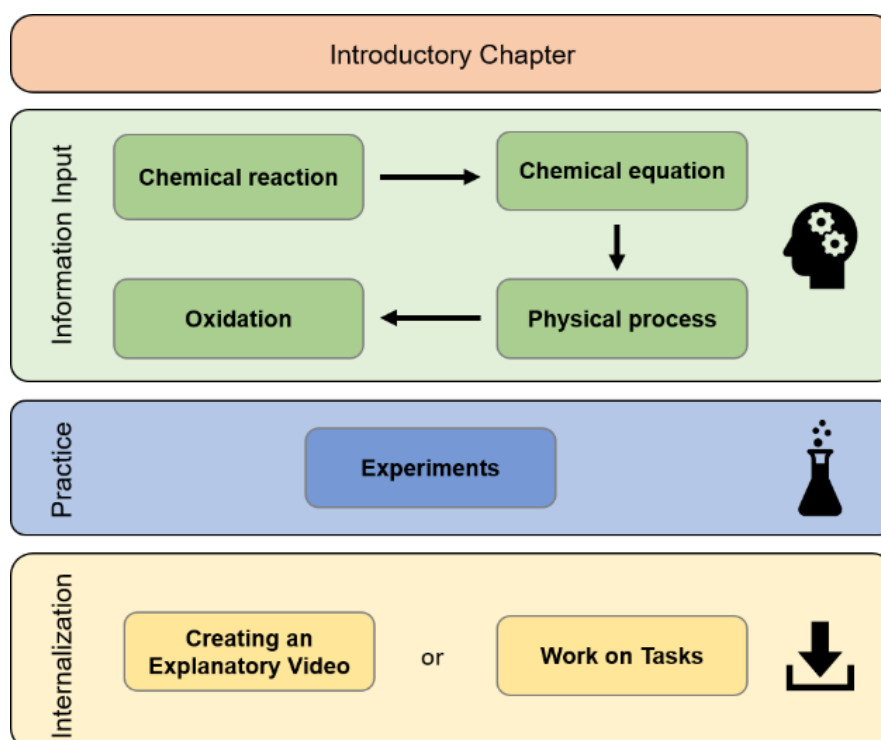


Figure 3. Structure of the iPad-based Learning Environment

As part of the transfer of the laptop-based learning software to an *iBook*, we made some optimizations and improvements. The main focus was on the implementation of further aspects of the UDL that were offered by the new technology. It should first be mentioned that differentiated learning paths are provided in each chapter. Accordingly, the chapters can be processed at three different levels, whereby the UDL guidelines two and six are addressed. The selection of the level is based on a self-assessment by the learners (guideline 3). In addition, digital index cards for an independent revision have been integrated at the end of each chapter to support the students, particularly in terms of internalization the contents (guidelines 3, 6 and 9). Another major change in the learning software is the integration of experiments, which promotes physical actions (guideline 7). The experiments were not digitally supported in the initial learning software by Baumann and Melle [19], but were guided by analogue paper-pencil-materials. By modifying the learning environment for the use on iPads, the experiments could be digitally supported in order to additionally meet the aspect "tablets as an experimental tool" [18]. Within the framework of this experimental phase, the students got experimental boxes as a structuring aid (guidelines 3 and 9). In addition, we attached great importance to repeating specific structures, hence, each experiment is marked by the same phases, execution, observation and evaluation (guidelines 6 and 9). With regard to the documentation of the experiments, it should also be mentioned that the learners are offered different choices (guideline 8): Either they can document the experiment through a photo documentation and a before/after comparison, or they can describe their observations in writing or in form of drawings. Unlike laptops, the easy handling of iPads is another great advantage as the touch functions of the iPads enable intuitive control of the devices by the students. Due to research interests, it is not possible for the students to take the iPads home with them. This is a limitation of this study as it does not allow students to access their results at home. In future, however, all students will probably be able to have their own iPads and access their learning material at any time.

Overall, we realized an interactive presentation of information. For example, the content is also communicated through short video sequences. By providing visual representations of the theoretical contents through these videos, the students are additionally addressed and supported on the iconic level. Moreover, the students are given the option of having the texts of the learning environment read aloud.

4. First Evaluation of the *iPad*-based Learning Software

In the following part, we focus on the information input and the experimental phase (cf. Figure 3) because in a first step we would like to evaluate if the laptop-based learning unit can be transferred to iPads. Therefore, the results of the internalization phase will not be presented. As these are the results of a pilot study with a small sample, the results should be considered preliminary and should not be over-interpreted. The following research questions are to be answered within the framework of this pilot study:

What influence does the digital learning environment (without the internalization phase) have on (a) the increase in expertise and (b) the attractiveness for the students?

4.1. Results

A first evaluation of the *iPad*-based learning environment took place in the context of a pilot study at general schools (lower secondary level, age 13-15) with a sample size of $N = 50$ students. Overall, six students with learning disorder participated. Unfortunately, we could not evaluate the results of two students (one of them with learning disorder) because they were not present at all testing times during the intervention, so that in total 48 students (five of them with learning disorder) could be tested within the study. In order to measure the effectiveness of the digital learning environment, a knowledge test (cf. [19,43], Cronbach's $\alpha = .769$, 28 items) and an attractiveness test (cf. [37], Cronbach's $\alpha = .821$, 10 items) were used.

Table 1. Analysis of the Results of the Knowledge-Test Using *t*-Test for Paired-Samples

Students	<i>n</i>	M_{pre}^*	SD_{pre}^{**}	M_{post}^*	SD_{post}^{**}	<i>p</i>	<i>d</i>
All	48	.29	.10	.50	.17	<.001	1.549
Without LD***	43	.30	.10	.52	.17	<.001	1.609
With LD***	5	.21	.10	.38	.14	<.001	1.386

*percentage

**standard deviation.

***LD = learning disorder.

Table 1 shows the results of the knowledge test. The expertise in chemical reaction has increased significantly from $M_{pre} = .29$ to $M_{post} = .50$ for all students ($n = 48$). It also becomes clear that the students without learning disorder have a higher percentage of correct answers in both, the previous knowledge test and the post-test, than the students with learning disorder. These differences between the students with and without learning disorder are almost statistically significant (pre: $p = .053$, $d = .930$; post: $p = .081$, $d = .891$; *t*-test for independent-samples).

Figure 4 shows a graphic representation of the mean values of the knowledge test. While the orange line shows the students without learning disorder, the grey line visualizes students with learning disorder. The mean value of all students is represented in blue. It should be noted that the averages of the pre-post results of both groups are almost parallel, while students with learning disorder are found above those without.

Furthermore, the learners assess the digital learning environment as attractive, which can be seen from the mean values of the results of the attractiveness test (cf. Table 2). The students rated the learning software as attractive with a mean value of $M = 5.03$ on a 6-point Likert scale from 6 (positive) to 1 (negative). Regarding these results, we again found differences between the two groups of students: Accordingly, the digital learning environment is rated a little more attractive by the learners without learning disorder ($M = 5.05$) than by the students with learning disorder ($M = 4.84$). However, these differences are not statistically significant ($p = .516$, $d = .328$; *t*-test for independent-samples). Compared to the laptop-based learning environment the results are generally similar in terms of the increase in expertise and attractiveness [19].

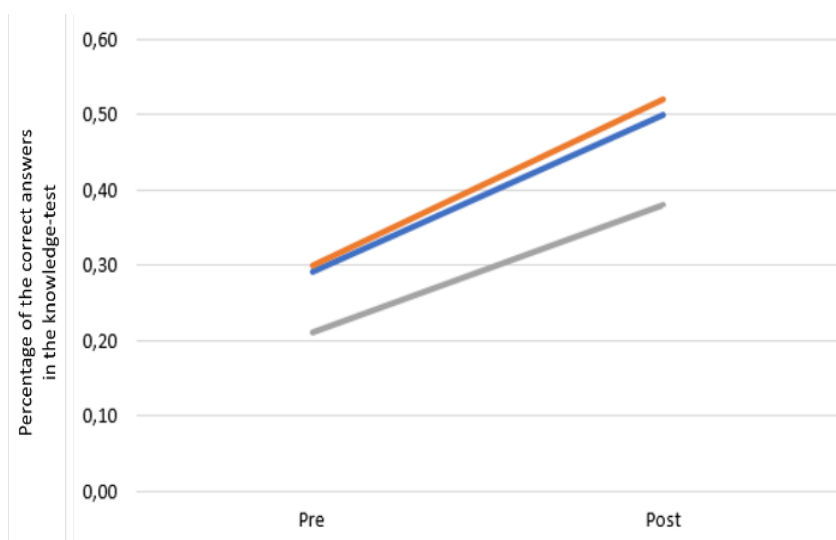


Figure 4. Plot of the Results of the Knowledge-Test (grey = students with learning disorder, orange = students without learning disorder, blue = all students)

Table 2. Analysis of the Results of the Attractiveness-Test Using *t*-Test for Paired-Samples

Students	<i>n</i>	<i>M</i> *	<i>SD</i> **
All	48	5.03	.68
Without LD***	43	5.05	.69
With LD***	5	4.84	.59

*6-point Likert scale, I totally agree (6, positive) to I totally disagree (1, negative)

**standard deviation

***LD = learning disorder.

4.2. Conclusion

Based on the results presented in the previous chapter, it can be assumed that the transfer of the laptop-based learning environment for the use on iPads succeeded. In summary, the iPad-based learning environment leads to a significant increase in expertise in the subject of *chemical reactions* - for both, students with and without learning disorder. Based on our results (see Figure 4, Table 1), the digital learning environment can also be regarded as an efficient differentiation method. Effective differentiation means that each student is supported as optimally as possible at his individual level, while homogenizing the learning group is not the aim of effective differentiation [46,47]. The digital learning environment is also perceived as very attractive by both student groups, with and without learning disorder.

However, the results of the study must be considered carefully due to the small sample size. Since students with learning disorder or in general students with special educational needs only make up a small proportion of inclusive classes, it is generally difficult to obtain statistically meaningful data on these students.

5. Outlook

We are going to expand the evaluation of the use of the iPad-based digital learning environment in a following study with a sample size of $N \approx 300$ in order to obtain meaningful conclusions regarding the research question mentioned above. Furthermore, the video and screen

recordings made during the intervention are to be evaluated in order to investigate the usage behavior of the students. Therefore, different coding manuals are necessary in order to analyze these data. Beyond that, we are going to analyze the effects of the learning software on learners of different cognitive levels, so that, for instance, conclusions about the impact of the learning environment (e.g. expertise and attractiveness) on students with lower and higher cognitive skills can be drawn. Finally, we are going to compare the two digital ways for internalization: creating explanatory videos vs. editing tasks on the iPad.

Acknowledgements

We thank the participating teachers and students. The tablet-based learning software was developed as a part of the project DoProfiL. This project is part of the "Qualitätsoffensive Lehrerbildung", a joint initiative of the Federal Government and the Länder which aims to improve the quality of teacher training. The programme is funded by the Federal Ministry of Education and Research.

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