TEACHING SOFTWARE SKILLS USING A FREELY ACCESSIBLE LEARNING SPACE - AN OER APPROACH

A.-K. Mertineit[1], K. Schaper[1], C. Bohrmann-Linde[2], D. Burdinski[3], B. Zulauf[1], N. Meuter[2], H. Hackradt[3], R. Kremer[2]

[1]*Heinrich-Heine-Universität Düsseldorf (GERMANY)*
[2]*Bergische Universität Wuppertal (GERMANY)*
[3]*Technische Hochschule Köln (GERMANY)*

Abstract

A wide variety of skills and competencies using digital tools are needed at universities, technical colleges, and later on in the professional world. The current generation of students is often described as digital natives. However, deficits in dealing with digital tools are evident.

OER.DigiChem.NRW aims at students who would like to expand and consolidate their skills and competencies using chemistry-related and general software. The collaborative project of Heinrich Heine University Düsseldorf, Bergische Universität Wuppertal and Cologne University of Applied Sciences is developing specific interactive video tutorials as Open Educational Resources (OER), which will be integrated into the learning management systems (LMS), ILIAS and Moodle. These materials will be provided to teachers and learners on ORCA.nrw, the learning platform of the German state North Rhine Westphalia (NRW), ensuring a long-term implementation of the created materials. Specific quality requirements have to be met by the OER: The basic prerequisites of analysis, design, development, implementation and evaluation have to be guaranteed by all project members and ORCA.nrw. A quality management system has been established that enables the reflection and the adjustment of the process at different points in time by everyone involved in the project.

The main questions in the project were how the didactical design of the learning materials and e-tutorials can be prepared in a way that enhances learning, and what social and technical challenges students have to deal with.

The produced videos are complemented by various learning materials: these include exercises to go with each video, with which the students can review their own learning, as well as cheat sheets with important shortcuts for each software. Different levels of the students' senses (visual and auditory) are addressed, so that deep processing of what has been learned is possible.

After implementation of the created learning materials in the LMS, learning effects were surveyed. Central topics were:

- Is the complexity of the tasks appropriate?
- Does the design of the learning space support learning with regard to functionality and design?
- Do the students grasp the teaching goals?
- How much experience do students have with e-learning, especially in self-study, and does the frequency have an influence on the above questions?

The evaluation results (n=37) indicate that tasks are not too complex (multiple item query; 57% and 82%). When queried on several items, it is evident that both the design of the learning space (61%) and its functionality (43%) influence learning. The results show that the structure used supports learning (54%). The learning outcomes are well-implemented in the videos and materials from the students' point of view (89%). Most students have already gained a lot of experience in using digital tools and feel confident in using them (78%).

The quantitatively collected results are subsequently substantiated by means of > 15 semistandardized interviews. Location- and time-independent transcriptions are created using MAXQDA software. Analyses of the online questionnaires by means of SPSS or R allow the comparison of thematic overlaps, and are automatically done by the software through the integration of categorizations. Through the mix of methods, an overall picture of the learning behavior as well as the didactic-psychological design of the learning space can be compiled.

1 INTRODUCTION

During the project, a wide variety of questions have been addressed: from the didactic design of the tutorials and learning materials to the structural design of the learning space. The cross-site quality management system plays a major role in the whole process, to ensure that the materials are designed in the same way and that the preparation can be done in either of the three universities.

With the project "OER.DigiChem.NRW", high school and university students can access professionally prepared material in order to expand or to consolidate their skills in the use of various software. The design of the learning material on a didactic as well as on a technical level is a central factor in this process. How can materials and tutorials be prepared to promote learning? Are the contents conveyed too complex or too simple and thus interfere with motivation and cognitive capacities? Do the materials offer the opportunity to build on and expand existing schemata based on prior knowledge? The OER.DigiChem.NRW team has addressed these and other questions in relation to Sweller's Cognitive Load Theory (CLT)[1] and has conducted extensive evaluations.

After the pre-evaluation and extensive adaptation of the didactic design of the learning material, the learning space and tutorials, with a focus on the creation of templates for the creation of uniform didactic elements as well as the structure of the self-learning space in ILIAS and Moodle (cf. Figure 1), the post-evaluation primarily surveyed learning effects and the cognitive load of the learning material, as well as the learning space on the learner. The CLT according to Sweller was used and combined with the multimedia theories according to Mayer[2] and Kerres[3].

The results of the evaluation (n=38) show that women (M = 2.23; SD = 0.416) and men (M = 2.14; SD = 0.314) do not differ significantly on average. Differences in the difficulty of the learning material and gender cannot be found. A relationship between the design of the learning space in terms of accessibility and design of the presentation with extrinsic cognitive load is not evident. No significant correlations can be identified for content complexity in relation to intrinsic cognitive load either.

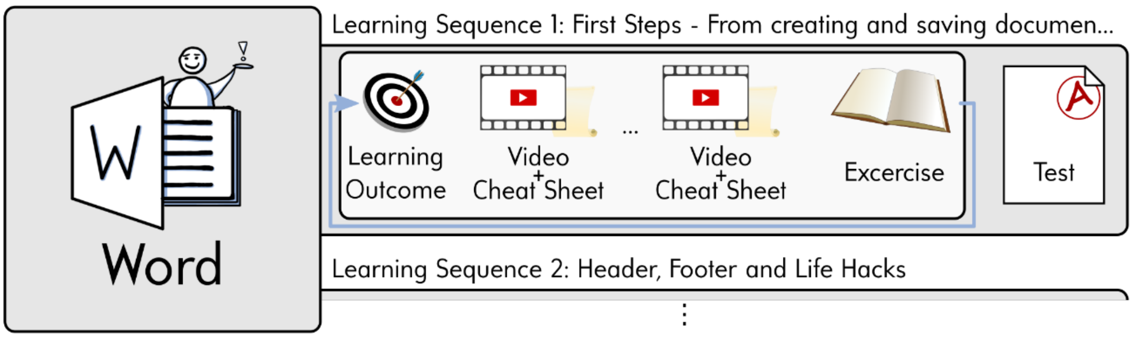

Figure 1. Sample design of the learning space. Each program has several learning sequences. Each learning sequence may consist of one or several topics. Each topic has the same structure: Introduction of the intended outcome, one or several videos on the topic and an exercise at the end of the topic. The learning sequence itself is concluded with a multiple or single choice test.

2 METHODOLOGY

Based on the results of the pre-evaluation, after the revision of the self-study room in the learning management systems ILIAS and Moodle as well as the first tutorials, all of the students´ recommendations for improvement of our materials were implemented in the following production phases, including the integration of a speaker during the intro and outro of a video or the use of a spotlight as a didactic element to highlight important issues during the screencast in the videos.

A mixed-methods approach was chosen for a comprehensive examination of cognitive load. First, the quantitative survey on aspects of the learning space and learning materials was conducted by an online questionnaire via the LimeSurvey platform.

This included three main areas:

- The design of the learning space in relation to the accessibility and design of the presentation (text-image design).
- The design of the learning space in relation to usability (navigation, orientation, and click-through).
- The quality of the content in relation to the complexity of the learning material.

After instruction, students were directed to a replicated homepage of the learning space in ILIAS. Then, students clicked on the "Word icon" and were taken to the overview page where the title and video were uploaded. After watching the video and completing the short exercise, students were directed back to the learning space and answered subsequent questions related to the areas described above.

Using the online questionnaire, the three domains previously described were surveyed. A 5-point scaling also reflected neutral opinions. With adaptation of the item number and slight change of wording, the first two scales, as well as the 5-fold scaling, were adopted from Hessel[4]. The scales surveying the quality of the content are self-designed. An exploratory factor analysis precedes, but is not considered in detail here. To consider gender differences in relation to the three scales as a function of CLT, independent-samples t-tests were conducted for each scale. To establish a relationship between intrinsic (ICL), extrinsic (ECL), and germane cognitive load (GCL) and the three domains, simple linear regressions were performed for each.

The guide for the semi-structured interviews was created based on the dimensions of the questionnaire. After completion of the quantitative survey, 14 semi-structured interviews were conducted, in which reference was made to the three main areas as well as some areas in particular depth; for example, the structure of the learning space or the relevance of the content for studying, which was mainly related to visibility by the university, student councils or similar institutions. The transcription and analysis of the interviews was carried out using MAXQDA software, which makes it possible to relate the quantitative data to the qualitative interviews. For transcription, three research assistants were extensively trained by a research assistant from the department. The analysis was done using grounded theory, which makes it possible to obtain insights from the materials during the research process and to categorize them so that specific areas can be referred to in more detail during further interviews. Thus, insights and theories can be generated from the data material. The basis for the analysis of interviews with Grounded Theory is Hermeneutics[5], which is why researchers need to have prior and background knowledge about the subject matter. As initial analyses are conducted during the research process, recognizable phenomena can be highlighted and examined in more detail in the further process.

The first two scales in the questionnaire are related to the representation of the overarching software products, such as MS Office, literature management programs, or chemical drawing programs by means of the self-designed drawings. Special attention was paid to navigation and clicking on to find out whether the structural design of the learning space supports or hinders learning. Since the use of learning sequences has been integrated into the learning space from the beginning, this was particularly looked at. The didactic design of the learning materials was surveyed in detail in the pre-evaluation. In the continuing process the focus was now on the complexity of the content and the relevance of the learning material for the study. Central questions were, for example, if the students transferred the use of the software to their further studies, whether the content corresponded to the students´ learning level or whether the motivation to continue learning was stimulated.

3 RESULTS

The learning management systems ILIAS and Moodle represent the didactic and technical basis for the learning materials. Continuous monitoring of the LMS is guaranteed so that any technical or content-related problems that occur can be permanently rectified. Evaluations in the form of online questionnaires and interviews offer a good opportunity to map goals, wishes and needs at all levels.

As already explained at the beginning, the learning space, and therefore also the included learning materials, are based on the needs of the students. The results from the pre-evaluation[6] were included in the further processing and finally evaluated in the following post-evaluation.

The focus was on the investigation of the cognitive load in relation to the following areas:

- Accessibility and design of the presentation (text-image design)
- Usability (navigation, orientation and clicking on)
- Complexity of the learning material

3.1 Descriptive evaluation

The majority of students (n=38) are between 23 - 25 years old (36.8%), female (57.9%), and enrolled in a Master of Science program (55.3%) at a university in chemistry (42.1%)

3.2 Item generation

The Text-Image Design scales were adapted from Hessel with a slightly modified item number. The five-item rating scale was retained. The item numbers were shortened from 23 to 17 items because the additional items focus on the design of a website, which is irrelevant to the information retrieval of a learning space. The reliability with an item count of 17 is $\alpha = .53$. The usability questionnaire was adopted in a shortened version from Hessel[4] as 39 statements relate to personal attitudes with the navigation of the learning program specifically used in the study. The reliability of the 7 items used is $\alpha = .88$. The scale on learning objectives and the complexity of the learning material was tested by means of a pre-test.

The structure of the instrument for the survey on learning objectives and the complexity of the learning material was tested by means of an exploratory factor analysis. Both Bartlett's test (Chi-Square (136) = 451.244, $p < .001$) and the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO = .720) indicate that the variables can be used for a factor analysis. Thus, a principal component analysis with varimax rotation was performed. Although this indicates the presence of four factors with eigenvalues greater than 1.0, based on the Scree plot and theoretical considerations, a three-factor solution was chosen, explaining 59.36% of the variance. Thus, three factors are present: "importance of content," "difficulty of content," and "transferability of content." The cross-loadings indicate that the second factor cannot be clearly separated from the other two. Based on prior knowledge of the content, this solution can nevertheless be assumed.

The referenced items of the CLT are taken from Klepsch et al.[7]. Reliability and validity of the items are assumed based on the data.

3.3 Accessibility and design of the presentation

The accessibility and design of the presentation in the learning space seems to keep extrinsic cognitive load low ($M= 2.52$, $SD= .328$). Differences between males ($M = 2.44$; $SD = .337$) and females ($M = 2.55$; $SD = .325$) cannot be detected ($t (34) = -.922$, $p = .962$). Cohen's effect size is $r =.33$ and corresponds to a medium effect.

The simple linear regression with the design of the learning space in terms of accessibility and design of presentation as the dependent variable (AV) and extrinsic cognitive load as the independent variable (UV) shows no significance, $F (1,37) = 2.847$, $p = >.001$. No relationship can be found between the preparation of the learning space and the level of extrinsic load.

Although not significant, the results suggest that the information content of irrelevant information and excessively long texts is kept low. This is supported by the findings from the interviews. In the evaluation of six interviews with students from the University of Wuppertal and the Heinrich-Heine-University Düsseldorf, all students indicated that there was no unnecessary information in the learning space. Likewise, the structure of the start page was emphasized several times. Above all, the self-designed icons based on the Bikablo drawing technique (cf. Figure 3) were described as visually appealing and innovative.

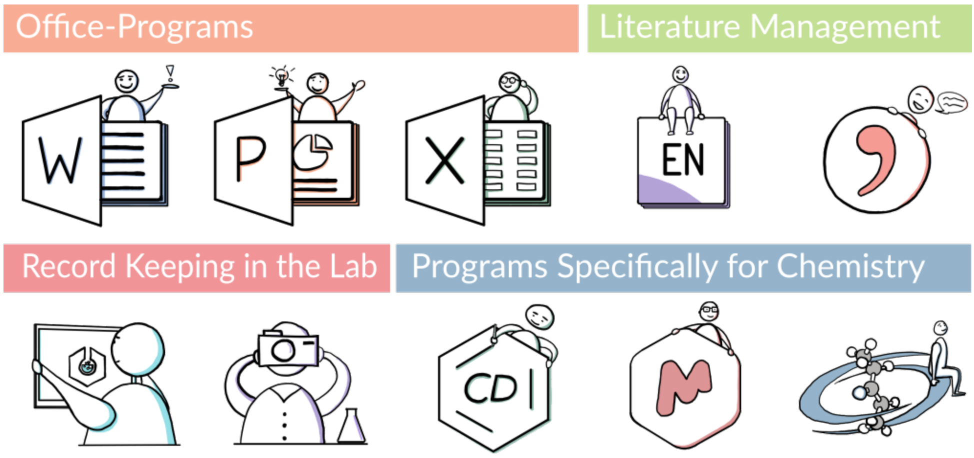

Figure 2. Example of Bikablo Drawings

3.4 Usability

On average, a low level of stress can be seen in the navigation and orientation of the learning space (M = 2.46; SD = .84). Similarly, when asked about the design of the learning space in terms of usability (navigation, orientation, and clicking on), no difference can be found between males (M= 2.485; SD = .890) and females (M= 2.40; SD= .88). The difference was not significant (t (35) = .281; p = 6.51). Cohen's effect size was r =. 88, corresponding to a high effect. A correlation of extrinsic cognitive load and the usability of the learning space cannot be found (F (1, 38) = 1.959, p = >.001).

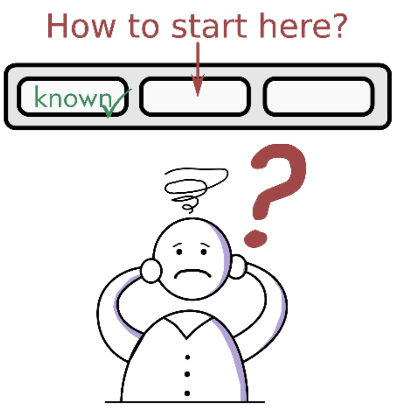

Figure 3. Students that are already familiar with one topic in the learning sequence, have no idea, how to start at their desired topic.

Nevertheless, the results suggest that the navigation did not keep the extrinsic load too high. This can be supported by the interviews. The start page was found to be intuitively understandable, as especially the large boxes with the link to the respective software offered a good overview and this via images only. However, difficulties were noted in processing the learning sequences. Four of the six students stated that they did not find the learning sequences easy to follow because they had difficulties with the structure. For example, it was not obvious that it was possible to navigate through the curriculum and thus skip videos and exercises in order to start with the content that was of interest to them (cf. Figure 3). Therefore, a content page is advocated where all videos as well as exercises and notepads are listed. This provides structure while allowing free choice of learning content.

3.5 Complexity of the learning material

The results indicate a low complexity of the learning material (M = 2.2; SD= 0.37). However, no significant relationship can be found between the difficulty of the learning material and gender (t (35) = .724, p = .254). Cohen's effect size is r =.36 and corresponds to a medium effect.

No significant results were found in the regression of content complexity as the dependent variable and intrinsic cognitive load as the independent variable (F (1,37) = 2.909, p = > .001).

It can be suggested that the content was too low in complexity to elicit a learning effect. However, the interviews suggest a different perspective. The students particularly emphasize the structure of simpler content, such as creating page breaks in Word to editing complex formulas in Word. The repetition of even previously learned information has solidified a sense of confidence in the students' abilities and motivated them to continue.

3.6 Video elements

As already asked in the pre-evaluation, a particular focus of the project is on the didactic design of the e-tutorials. Deeper insights could now be obtained through the interviews.

In order to promote the attention of the listeners, video elements can be helpful. In the e-tutorials, we decided to use a spotlight so that the background is grayed out and a bright circle follows the mouse. This element was found to be particularly helpful in all six interviews, as it provides structure and, on the other hand, also prevents misunderstandings and being overwhelmed, thus saving time. Likewise, the feedback on the keyboard used to link images and text was positive in the sense that it created a positive learning experience. Intros and outros were used to create structures that supported students, firstly by framing the unit and secondly by associating voice with a person. A presentation given by a real person increased motivation to listen and watch the entire video.

3.7 Exercises and notepads

In addition to the videos, exercises are offered in written form as a supporting medium. These take what has been learned from the video, and are intended to deepen the learned knowledge and to tie into the previous knowledge. However, it became clear in the interviews that the students show a different learning behavior: while working on the videos, the software explained in the video was opened in parallel and the newly learned function was tried out immediately. For this reason, three students stated in the interviews that they did not need any exercises (cf. Figure 4). However, the students found the exercises to be well-prepared in terms of content and appearance, since only the essential information and elements occurred. Extrinsic cognitive load was low. As a supportive medium, all six students cited the notepads with the most important shortcuts placed under each e-tutorial. Above all, looking up the most important shortcuts later saves time and consolidates knowledge, so that this primarily addresses and supports the GCL.

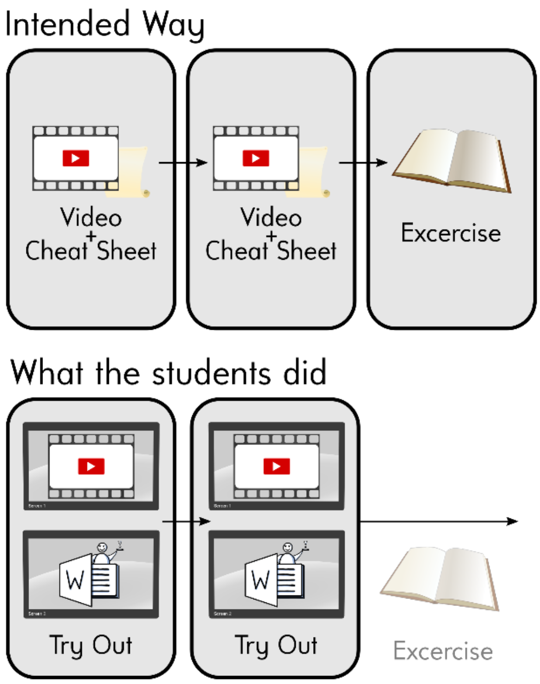

Figure 4. Instead of following the intended way – watching the videos and work on an exercise to familiarize themselves with the topic – students tried to replicate the things shown in the video while watching and skipped the exercise afterwards.

4 CONCLUSIONS

Quality in the production of learning materials and tutorials is a central aspect in the design of open educational resources and is discussed in literature[8]. Mixed methods can be used to provide detailed and profound answers to a wide range of questions in the media design of e-learning offers.

By means of the standardized evaluation as well as the semi-structured guideline interviews, a variety of results could be obtained. However, it should be noted that the size of the sample can distort the data. In particular, the effect size may be reduced as a result. When answering the online questionnaire, 172 students participated. Yet, only 38 questionnaires could be analyzed because students did not return to the survey after visiting the learning space. It is reasonable to assume that the students took part in the survey via their smartphones, as the redirection to the learning space does not occur in a new tab when edited on a smartphone. This is only possible when editing on a PC, laptop or tablet. The evaluation of the learning space was also not designed for editing on the smartphone, since the LMS, ILIAS and Moodle, do not have the same display as on a PC or laptop. For example, headings, tiles or images are covered or displayed too largely. If learning spaces are oriented to the current use of the smartphone, these problems could be limited.

The guideline for the semi-structured interviews reflects all three dimensions of the questionnaire and elaborates on individual areas; for example, the structure of the learning space in relation to the learning sequences. Representativeness is particularly important in qualitative research. The theoretical construct provides a framework of information to be exhausted, also known as theoretical saturation[8]. The funding line specified > 15 interviews as the target. There is no consensus in literature on the exact number of interviews defined. However, 6 - 10 interviews can be mentioned as a framework for exploratory questions. As it turned out, theoretical saturation occurred after about 7-9 interviews, so that no new knowledge was available. Thus, effectiveness and efficiency are not in line with the theoretical gain of knowledge.

Even though today's generation of pupils and students are considered digital natives, there is still a need to promote their competencies in their use of digital resources and software. A basis for this is usually set at school, although often to very different extents. It thus needs to be further expanded during studies in tertiary education. Not least due to the pandemic, digitalization has taken a big step forward in education. Working with learning platforms is now quite common and learning videos are among the most frequently consulted sources of information. Due to this, it is essential to investigate the design of learning spaces and videos, especially with regard to a low extrinsic cognitive load, and to derive designing principles from them. The presented study is meant as a contribution to this. It is precisely this demand for further digital offerings and opportunities that is central among students. In the interviews, it became clear that lecture recordings continue to be a good way to use digital offerings in order to prepare optimally for exams and to promote work-life balance. However, students indicated that few to no structures are offered by universities. This demand refers on the one hand to the possibility of self-designed learning spaces, but also to the explanation of the structures of the learning spaces used during lectures or seminars. The uncertainties that arise due to the overload of the respective media overshadow the learning content and lead to frustration and loss of motivation. The breaking up of fixed structures in order to combine the existing and the new and to learn from each other, both teachers and students, is more than ever a demand on politics and universities.

Even if great importance is attached to the best possible accessibility in the production of instructional videos and this is consistently implemented, new barriers can arise during implementation on a website or other web application, which makes access for users with disabilities significantly more difficult or even impossible. Digital e-learning platforms such as ILIAS and Moodle are not classically considered websites, but they are legally classified as such and must therefore provide barrier-free access to website standards. The basis for this is the EU Directive 2016/2012, which applies throughout Europe, and the EN 301 549 standard, which is also recognized as a German standard[9][10][11]. These guidelines are binding for public authorities and projects that are financed by public funds.

Possible barriers on e-learning platforms can be influenced by teachers only to a very limited extent or not at all, here the responsibility lies with the developers and is permanently discussed and developed further by both Moodle and ILIAS. Teachers are allowed a certain amount of freedom to provide and embed their content - "textual and non-textual information, documents and forms for downloading"[12]. For this reason, the self-study course OER.DigiChem had to be reviewed for a comprehensive consideration of the cognitive load, especially in terms of usability (navigation, orientation and amount of clicks) also from the perspective of disabled users. At this point, the recommendations of WCAG 2.1

from June 2018 should help[13]. From this it could already be deduced that the originally planned presentation of the course categories in "hand lettering" style, i.e., an image of text, is not accessible without alternative presentation[14].

For further review of the courses, the free web extensions WAVE[15] and the open source screen reader program NVDA were used. Especially in the digital learning space in ILIAS, an analysis using WAVE revealed significant problems with a total of 52 error messages. Of these, 18 were possible ARIA Errors[16], which would have to be checked by ILIAS itself. The remaining 34 error messages could mainly be traced back to missing alternative texts behind images, insufficient contrasts and omitted heading levels. These errors could be revised and fixed by the project members themselves, reducing the number from 34 to 2. However, testing with WAVE identifies problems only from a technical point of view and does not provide usability information for users navigating solely with the keyboard and screen reader[17]. A test use with NVDA showed additional deficiencies in the contextualization of links and missing headings, or awkward use of heading levels, which made content comprehension and the navigation with the keyboard very difficult[18]. The examination took place in this project, by a project member, who could acquire handling with this software only superficially. In the best case, this test is carried out by an expert, i.e., a person who is experienced in the use of NVDA or a similar program. This test will be made up for in the further course of the project. The fact that more barriers arose with ILIAS is mainly due to the aforementioned scope for design.

ACKNOWLEDGEMENTS

We would like to thank our Ministry of Culture and Science in North Rhine-Westphalia, the Digital University of North Rhine-Westphalia, the team of the ORCA.nrw project and all researchers and students of the three universities who supported us during the evaluation

REFERENCES

[1] Sweller, J., Ayres, P., Kalyuga, S. (2011): Cognitive Load Theory. Springer Science + Business Media. DOI 10.1007/978-1-4419-8126-4

[2] Mayer, E. R. (2014): The Cambridge Handbook of Muktimedia Learning. Cambridge University Press. https://doi.org/10.1017/CBO9781139547369

[3] Kerres, M. (2013): Mediendidaktik | Oldenbourg Wissenschaftsverlag 2. https://doi.org/10.1524/9783486736038

[4] Hessel, S., Die Bedeutung von Usability und cognitive load auf die Informationssuche beim multimedialen Lernen. Erfurt, 2009. urn:nbn:de:gbv:547-200900285

[5] Breuer, F., Reflexive Grounded Theory. Eine Einführung für die Forschungspraxis, Springer Fachmedien, Wiesbaden, 2010 doi: 10.1007/978-3-658-22219-2

[6] A.K. Mertineit, K. Schaper, C. Bohrmann-Linde, D. Burdinski, B. Zulauf, N. Meuter, H. Hackradt, R. Kremer, N. Knipprath, “COLLABORATIVE DEVELOPMENT OF OPEN EDUCATIONAL RESOURCES FOR BUILDING COMPETENCIES IN THE USE OF DIGITAL TOOLS IN CHEMISTRY,” *14th annual International Conference of Education, Research and Innovation,* P. 1111-1118., 2021 doi: 10.21125/iceri.2021.0325.

[7] Klepsch, M, Schmitz, F., Seufert, T., “Development and Validation of Two Instruments Measuring Intrinsic, Extraneous, and Germane Cognitive Load,” *Front. Psychol,* 8:1997, 2017. doi: 10.3389/fpsyg.2017.01997

[8] Mey, G., Mruck, K. (2010): Handbuch Qualitative Forschung in der Psychologie, VS Verlag für Sozialwissenschaften | Springer Fachmedien Wiesbaden GmbH.

[9] Richtlinie (EU) 2016/2102 Des Europäischen Parlaments und des Rates: Amtsblatt der Europäischen Union L237. Accessed: May 5, 2022. Retrieved from: http://data.europa.eu/eli/dir/2016/2102/oj

[10] European Telecommunications Standards Institute. Accessibility requirements for ICT products and services EN 301 549 V2.1.2 Accessed: May 5, 2022. Retrieved from: https://www.etsi.org/deliver/etsi_en/301500_301599/301549/02.01.02_60/en_301549v020102p.pdf

[11] Verordnung zur Schaffung barrierefreier Informationstechnik nach dem Behindertengleichstellungsgesetz (Barrierefreie-Informationstechnik-Verordnung - BITV 2.0).

Accessed: May 5, 2022. Retrieved from: http://www.gesetze-im-internet.de/bitv_2_0/BJNR184300011.html

[12] Moodle documentation. Accessed: May 5, 2022. Retrieved from: https://docs.moodle.org/310/de/Barrierefreiheit

[13] W3C Recommendation. Web Content Accessibility Guidelines (WCAG) 2.1. Accessed: May 5, 2022. Retrieved from: https://www.w3.org/TR/WCAG21/

[14] W3C Recommendation. Web Content Accessibility Guidelines (WCAG) 2.1, 1.4.5 images of text. Accessed: May 5, 2022. Retrieved from: https://www.w3.org/TR/WCAG21/#images-of-text-no-exception

[15] WebAIM. Institute for Disability Research, Policy, and Practice Utah State University. Accessed: May 5, 2022. Retrieved from: https://wave.webaim.org/about

[16] NV Access Limited. Accessed: May 5, 2022. Retrieved from: https://www.nvaccess.org/about-nv-access/

[17] W3C Recommendation. ARIA (Accessible Rich Internet Applications) in HTML. Accessed: May 5, 2022. Retrieved from: https://www.w3.org/TR/html-aria/

[18] W3C Recommendation. Web Content Accessibility Guidelines (WCAG) 2.1, 2.4 Navigabel. Accessed: May 5, 2022. Retrieved from: https://www.w3.org/TR/WCAG21/#navigable