Supporting the Flipped Classroom Approach to Higher Education Through a Computer-Based Learning Environment

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Received: October 5, 2022 Accepted: December 15, 2022 Online Published: December 22, 2022

doi:10.5430/ijhe.v11n6p154 URL: https://doi.org/10.5430/ijhe.v11n6p154

Abstract

This study exemplified two successful implementations of a flipped classroom approach using the computer-based learning environment *Toolbox TeacherEducation* (TTE) integrated into two separate university courses. We questioned how the TTE can be used in a flipped classroom to teach and learn successfully and how participants' self-regulated learning and user experience contribute to learning. We analyzed two university courses (N_1 = 34, N_2 = 73) designed as flipped classrooms. To measure knowledge increase, we developed multiple-choice items to collect knowledge before and after learning. Participants showed a significant learning gain in both courses (average p = .025) with an average effect size of d = 1.02. Since self-regulated learning competencies and user experience affect computer-based learning, we addressed these concepts using different questionnaires. Regarding self-regulated learning, the participants reported above-average skills, but we did not find meaningful correlations with learning. Regarding user experience, the participants rated the TTE as highly usable and well designed. Based thereon, we showed how the TTE could be implemented in a flipped classroom to teach and learn successfully.

Keywords: flipped classroom, computer-based learning environments, higher education, self-regulated learning, user experience, Toolbox TeacherEducation

1. Introduction

Considering the increasing number of teaching methods, digital learning, and the diversity of learning styles in higher education, the adequacy of traditional lectures is increasingly questioned (Goedhart et al., 2019; Mingorance Estrada et al., 2019). Research on learning shows that doing is more beneficial for learning than listening, which is mainly practiced in traditional lectures (National Research Council, 1999). Therefore, different teaching methods were proposed, where practical, hands-on activities are focused on during the lectures (e.g., Day & Foley, 2006; Mason et al., 2013). One popular teaching method is the flipped classroom (FC) approach. Here, the knowledge acquisition in a traditional lecturer-up-front style is moved outside of the classroom to a self-study phase, and active learning exercises are moved inside the classroom (Gannod et al., 2008; Strayer, 2012).

Outside the classroom, learners study independently, mainly using digital media to prepare for the following course (e.g., Papadopoulos & Santiago Roman, 2010; Tune et al., 2013; van Alten et al., 2020). Consequently, we posed the question of how digital tools enrich the FC method. Therefore, we present two university seminars where the FC and a computer-based learning environment (CBLE) come into action.

We want to demonstrate the advantages of the FC approach and two successful implementations of a CBLE into an FC. Hence, our approach contributes to the research on teaching and learning in higher education. Thus, the present work evaluates the impact of the FC on learning in real university seminars and how a publicly accessible CBLE can be implemented feasibly to support the FC teaching approach. Moreover, we address self-regulated learning (SRL) and user experience (UX) because these concepts play crucial roles in digital learning and self-studying (see chapter 2.2 The Role of SRL and UX in FCs; Mandl & Bürg, 2008; van Alten et al., 2021).

2. Literature Review

2.1 Flipped Classroom in Higher Education

The FC approach describes the relocation of (theoretical) knowledge transmission outside the classroom to a self-study phase (first by Lage et al., 2000 as the "inverted classroom"). Issues and problems can be discussed profoundly in class because the learners already have a basic understanding after self-studying (Bates & Galloway, 2012). Sources for the self-study phase can be articles, pre-recorded videos, or CBLEs (Day & Foley, 2006; Goedhart et al., 2019).

The advantage of an FC is that learners study at their own pace, resulting in an optimized learning process (Adewoye & Olaseni, 2022). The self-acquired knowledge can be activated and contextualized in class by engaging the learners in active learning exercises (e.g., individual or paired quizzes, open questions, pair and share activities; McLaughlin et al., 2014). By learning and preparing for the lecture, more time for hands-on activities (i.e., problem-solving or group discussions) during the class is available, which is beneficial for learning (Day & Foley, 2006). Already the Cone of Learning from Dale (1969) visualized that active participation and "doing the real thing" can improve retention more than passive listening. Moreover, a review from Prince (2004) shows that active learning results in higher learning gains and higher learner engagement than traditional lectures.

Overall, current research indicated that learners taught with an FC approach showed greater learning gains than those taught with a traditional lecture design (van Alten et al., 2019; Wagner et al., 2021). Furthermore, learners and lecturers reported positive feedback about the FC method (Bates & Galloway, 2012; Goedhart et al., 2019; Karabatak & Polat, 2020). However, learners need to be motivated to study, which can be encouraged by assignments and quizzes (Day & Foley, 2006). Bates and Galloway (2012) showed that 91% of learners regularly participated in quizzes. Additionally, learners need guidance and support to plan their learning and use efficient self-study methods (Adewoye & Olaseni, 2022).

Additionally, learners need to monitor and self-regulate their learning processes independently during self-studying. Thus, these SRL skills are essential competencies to ensure a successful FC design (van Alten et al., 2021). Consequently, we addressed and evaluated the reported SRL skills (see chapter 2.2.1 Self-Regulated Learning).

2.2 Flipped Classroom and Computer-Based Learning Environments

CBLEs provide learning opportunities including hyperlinks, video tutorials, and interactive visualizations, allowing learners to learn according to individual preferences (Goedhart et al., 2019). Moreover, using a CBLE can improve the efficiency of the learning process according to the *cognitive theory of multimedia learning* (Mayer, 2014). Visual and auditive content can be organized simultaneously and therefore accelerate the processing of the presented information. Because information processing is limited in its capacity, learning environments where visual and auditive information can be presented simultaneously are preferable (Mayer, 2014).

These benefits come in handy when CBLEs are considered as learning material for self-study phases. Because the comparison between traditional lectures and flipped classrooms has been researched extensively (for a meta-analysis, see van Alten et al., 2019), we focus on the feasibility of implementing a CBLE. We aim to show how a publicly available CBLE can be successfully integrated into a university seminar designed as an FC. Our approach is an example of use that has been scientifically proven to support effective learning and teaching (see Lewalter et al., 2020, 2022; Titze et al., 2021).

As a CBLE, for self-studying phases, we used the German hypermedia and interactive *Toolbox TeacherEducation* (TTE; Lewalter et al., 2018a). The TTE is an open educational resource focused on educating teachers. Furthermore, it offers a wide range of didactical, competency-, and evidence-based materials, achieving a transfer from theoretical knowledge about education to practice-oriented and teaching-related practice (Titze et al., 2021).

Components of the TTE comprise forms of multimedia presentations and designs that were created based on the *multimedia principle* to enhance learning success (Butcher, 2014). The components are complementary and can be used independently. This structure offers a high degree of flexibility during self-study phases. The TTE includes, for example, theoretical basics and video tutorials to build fundamental knowledge and, furthermore, instructional videos or learning tasks that propose hands-on activities to induce higher-level thinking skills (Churches, 2008; Krathwohl, 2002).

The *theoretical basics* show the state of research, different models, theories, and concepts in scientific written form, supplemented by figures or tables to build fundamental knowledge. *Video tutorials* visualize theoretical basics, making theories, concepts, and models more approachable and beneficial for cognitive processing (e.g., Mayer, 2005, 2014). *Scripted instructional videos* show different scenes from a class, including typical practice examples that outline everyday school life. Discussing the videos in class leads to hands-on activities, such as applying the basic knowledge learned and analyzing the teaching structure presented. *Learning tasks* can be used by learners to monitor their level of knowledge and receive immediate feedback in textual form (Lewalter et al., 2020).

The TTE can also be used during class (cf. Lewalter et al., 2020; Titze et al, 2021). For example, it can be used to repeat the learning content, which has been proven to promote learning (see enhanced inverted classroom-Model [EICM]; Schärtl, 2016). The TTE is organized in learning modules, including different topics within three disciplines of school practice: educational psychology (e.g., heterogeneity), subject didactics (e.g., problem-solving), and teaching subject (e.g., Pythagorean theorem). Every topic and module can be used separately or in combination according to individual requirements, resulting in a high degree of flexibility for the learner and lecturer.

This current study seeks to prove that CBLEs are a valuable tool for the FC method. Therefore, we present two FC seminars that integrated the open educational resource TTE as a CBLE (see chapter 3. Research Methods). Because the seminars were existing university seminars, high ecological validity, reliable results, and meaningful contributions can be expected. Because we consider the participants' UX and SRL skills as an important prerequisite for computer-based learning, we included questionnaires for these constructs (see Tables 3 and 4).

2.3 The Role of Self-Regulated Learning and User Experience in Digitally Based Flipped Classroom Settings

2.3.1 Self-Regulated Learning

The competency of SRL describes the essential role of regulating learning activities and strategies, which significantly affect successful learning (e.g., Winne & Hadwin, 1998; Zimmerman & Moylan, 2009). In the context of FCs, where the learners study independently, SRL skills are essential for successful learning. The self-study phases in an FC demand a high degree of learner control, leading to ineffective learning if the learners lack knowledge and skills about regulating their learning activities (van Alten et al., 2021). Therefore, SRL skills and knowledge about learning preferences can facilitate and promote computer-based learning (van Alten et al., 2020, 2021). Consequently, addressing SRL skills is a crucial when analyzing the effectiveness of FCs.

2.3.2 User Experience

To ensure effective and efficient computer-based learning, the user's experience must be considered (Rodgers et al., 2011). A positive UX will likely meet the user's needs, resulting in a high-quality interaction and enduring usage (Nistor et al., 2014; Peres et al., 2013). The following important concepts of UX are predominantly distinguished in the literature: usability, media design, and acceptance (Nistor et al., 2014; Rodgers et al., 2011).

Usability is defined as the effectiveness of completing a task, the efficiency of processing a task, and user satisfaction (DIN EN ISO 9241-11; International Organization for Standardization, 2018). Successful learning is likely if these concepts are experienced at a high level. Moreover, deficits of the CBLE can be recognized, thus the learning process can be adapted (Mandl & Bürg, 2008). In conclusion, assessing the UX is essential for analyzing computer-based learning.

3. Research Methods

This research aims to evaluate the FC method including the TTE used for self-studying in two different university seminars. Initially, the FC scenario was evaluated with a small sample to prove the usability and the impact of the TTE on learning (Seminar 1). In the next step, the FC scenario was evaluated with a more significant sample and an improved methodological structure (i.e., posttests after each topic; Seminar 2). Beside learning performance, SRL and UX were measured in both seminars (for structure of both seminars, see Figure 1).

As stated hitherto, we want to analyze if usage of the TTE embedded in an FC approach leads to a significant learning gain (RQ1). Furthermore, we described the importance of SRL competencies and UX associated with computer-based learning. Therefore, we asked, if SRL skills (RQ2) and UX (RQ3) influence learning performance (RQ2). We assume significant learning gains and a positive UX in the FC seminars supported by TTE in self-study phases. Furthermore, we hypothesize that high self-reported SRL skills correspond positively to learning gains.

3.1 Procedure

We implemented the FC seminar as follows: the university seminars consisted of six face-to-face (Seminar 1) or online (Seminar 2) sessions in which the participants discussed the contents from the prior self-study phases with the lecturer. Between each face-to-face or online session, five self-study phases took place. In them, the participants studied predefined content using the TTE and scientific articles (see Figure 1).

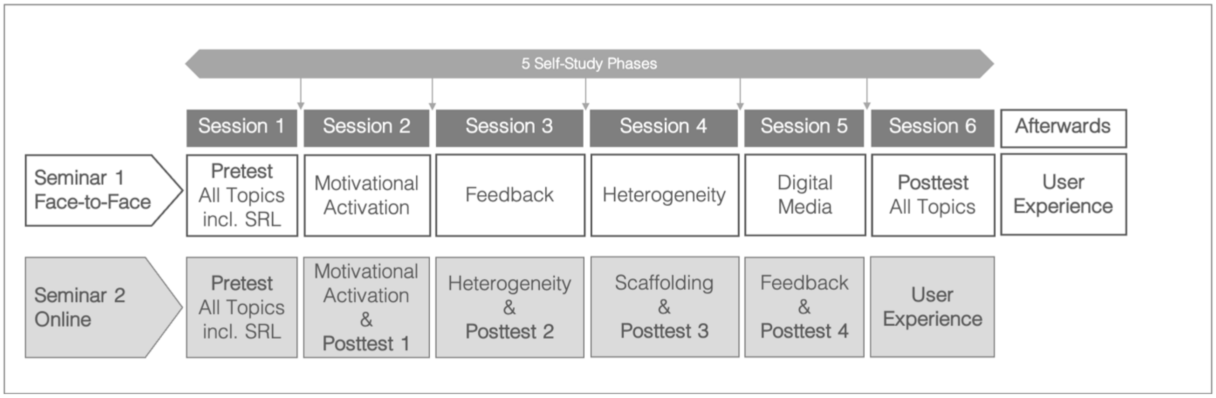

Figure 1. Contents, Structure, and Placement of Questionnaires for Seminar 1 Compared to Seminar 2

Note: SRL = Self-Regulated Learning Scale.

In both seminars, four psychological-educational topics were addressed (for sequence and sample size, see Table 1). Both seminars were designed as an FC. The TTE and additional scientific articles were used as learning materials during the self-study phases. In the first session, the structure of the seminar and the TTE were introduced, followed by alternating face-to-face sessions (for Seminar 2 online) and self-study phases for several weeks (see Figure 1).

The participants outlined the topic and uploaded the summary to a learning management system (i.e., Moodle). The task for the last topic of Seminar 1 (digital media) was to find a media tool and to present it afterward in front of the class. The face-to-face sessions were used in both studies to answer open questions and discuss issues (including the posttest for the topic in Seminar 2).

The pretest took place in the first session of both seminars, which included a declaration of consent and questions about SRL skills. In Seminar 1, the posttest for all four topics was filled in during the last session, and the questionnaire about UX was completed after the seminar due to scheduling reasons (see Table 1 and Figure 1, first row). We improved the sequence for Seminar 2, where the posttests were filled in according to the previous topic (i.e., the questionnaire about heterogeneity took place in session 3, after the self-study phase for heterogeneity; see Figure 1 last row). The questionnaire about UX for Seminar 2 was completed in the last session of the seminar (see Table 1 and Figure 1).

3.2 Participants

3.2.1 Seminar 1

The first seminar took place at the University of Saarland (Germany) in the winter semester (October 2019 to February 2020). Topics of Seminar 1 were motivational activation, heterogeneity, feedback, and digital media. The participants used the corresponding modules of the TTE during self-study phases. For each topic, a face-to-face session took place, which comprised discussing the theory, the tasks, and the videos and the transfer to professional practice in greater detail.

Participants were 34 university students consisting of 28 secondary school track studies and six vocational school track studies (M = 23.44 years, SD = 2.31; 19 females, 15 males). All 34 participants completed the pretest in the first session of the seminar, and 27 participants completed the posttest, which took place during the last session of the semester. At the beginning of each questionnaire, students were informed about data protection and had to give their consent by marking a box; otherwise, the questionnaire could not be started. The questionnaire about UX had to be filled in after the seminar due to time constraints, which led to a dropout of 17 participants (see Table 1). Therefore, the information on UX, which was part of the posttest, is indicative only for Seminar 1.

3.2.2 Seminar 2

The second evaluation took place in a seminar split into two groups at the same university with the same content in the summer semester from April to July 2021 (N = 73; 66 secondary school track studies and 7 vocational school track studies). The seminar topics were motivational activation, heterogeneity, scaffolding, and feedback. The didactical methods were equal to Seminar 1, although Seminar 2 was exclusively online.

The pretest took place in the first session at the beginning of the semester. In contrast to Seminar 1, the posttests in Seminar 2 were presented after each topic. Demographical data were retrieved from the questionnaire about UX, which took place during the last session at the end of the semester, resulting in a different sample size (*N* = 61; *M* = 24.13 years, *SD* = 3.97; 37 females, 24 males). All sample sizes can be seen in Table 1.

Table 1. Topics of Seminar 1 and Seminar 2 and the Respective Sample Sizes of Pretest, Posttest(s), and User Experience (UX).

	Seminar 1: Face-to-Face Sessions					
	1		6			After the Seminar
	Pretest incl. SRL	Motivational Activation	Feedback	Heterogeneity	Digital Media	UX
N	34		27			10

	Seminar 2: Face-to-Face Sessions (online)					
	1	2	3	4	5	6
	Pretest incl. SRL	Motivational Activation	Heterogeneity	Scaffolding	Feedback	UX
N	73	67	65	66	57	61

Note. SRL = Self-regulated learning scales.

In Seminar 1, the posttest about all topics took place in the last session of the semester (6).

In Seminar 2, the posttests followed the session for each topic.

3.3 Measurements

Processes and requirements that cause and navigate digital learning are manifold (Prenzel et al., 2001). Therefore, we addressed several different factors to generate a comprehensive understanding of the requirements for successful computer-based learning in the self-study phases of FC seminars. Thus, we included questionnaires about learning performance (self-designed knowledge test, included in the pre- and posttest; for item examples, see Table 2), SRL skills (existing scales, included in the pretest), and UX (existing scales, included in the posttest). All scales can be seen in Tables 3 and 4.

3.3.1 Learning Performance and Competencies

We developed a self-designed knowledge test to measure learning performance and acquired competencies. All items were specifically tailored to the contents of the TTE to get a meaningful value for the achieved learning gain. The questionnaires have been used in university seminars since 2018 and analyzed to ensure their validity (Lewalter et al., 2018b, 2022; Titze et al., 2021).

The test contains 45 content-related multiple-choice items for Seminar 1 and 46 for Seminar 2 (10 about motivational activation, 12 about feedback, 12 about heterogeneity, 11 about digital media, and 12 about scaffolding; example items can be seen in Table 2). Regarding the measurement of different competencies, items were classified into three difficulty levels based on *Bloom's (Digital) Taxonomy* (Bloom et al., 1996) and the hierarchically ordered *Thinking Skills* (Anderson & Krathwohl, 2001; Churches, 2008). The first level refers to recognizing and describing information. The second explains and predicts the learned content. The third is actively developing and reflecting on issues (see Lewalter et al., 2018b; examples of different competency levels can be seen in Table 2).

The participants were asked to complete the questionnaire before (to measure prior knowledge) and after learning (see chapter 3.1 Procedure). The calculated difference value (knowledge after learning–knowledge before learning) was used as an indicator for learning gain, whereas pre- and posttest values measured learning performance. We included "*I don't know*" and "*No answer is correct*" choices in every item to maximize measurement accuracy and minimize guess probability.

Table 2. Examples for Items on Different Difficulty Levels and Respective Competencies (Topic Digital Media)

Difficulty Level	Competencies	Item
1	recognizing and describing	*How can the Pedagogy Wheel help you to plan media-based teaching?*
2	explaining and predicting	*Which of the following statement(s) is/are true about the SAMR model?*
3	developing and reflecting	*Imagine the following scenario: The teacher introduces the topic of sine and cosine functions. The teacher uses geometry software and a beamer for visual presentation. How do you evaluate this situation?*

Note. Difficulty level 1 is the easiest, the difficulty level 3 is the most challenging.

3.3.2 Self-Regulated Learning Scales

We added SRL scales before learning at the beginning of the pretest (see Table 3 and Figure 1). Therefore, we chose the subscales about the SRL phase of forethought from the SRL questionnaire from Dörrenbächer and Perels (2016). The forethought subscale includes goal setting, planning, self-efficacy, and self-motivation. We chose this subscale because the items best fit our research interests and showed the highest reliability (see Table 3). We included Cronbach's α to examine whether the internal consistency corresponded to the results of the original scale (cf. Dörrenbacher & Perels, 2016).

Table 3. Scales for Self-Regulated Learning (SRL) and Item Examples (Dörrenbächer & Perels, 2016)

Scale	Cronbach's α	No. Items	Item Example
Goal Setting	0.70	4	*Before studying, I know exactly what grade I want to achieve in the exam.*
Planning	0.87	5	*Through systematic planning, I manage to work continuously.*
Self-efficacy	0.72	5	*I can find a solution to every problem.*
Self-motivation	0.72	3	*I am enjoying my studies.*

Note. 4-point Forced Likert Scale.

1 = not true at all, 4 = totally true.

3.3.3 User Experience Scales

Questionnaires about UX were placed at the end of the semester after the TTE learning platform had been used (see Table 4 and Figure 1). Therefore, we included the scale *performance expectancy* of the *Unified Theory of Acceptance and Use of Technology* (UTAUT; Venkatesh et al., 2003). The UTAUT is a model to predict users' behavior and the likelihood of using a technical device (Andujar & Medina-López, 2019). Productivity increases if the acceptance is high or positive (Venkatesh et al., 2003). The scale *performance expectancy* refers to the perceived advantage of the technology when solving a task, meaning how the technology can help solve the task (Venkatesh et al., 2003).

Moreover, we chose the German version of the questionnaire *Perceived Website Usability* to evaluate usability in greater detail (PWU-G; Thielsch, 2017). Because multimedia and interactive components of a CBLE are meaningful for learning, we included items to analyze if the participants perceive the multimedia design as useful. The questionnaire *Medial Design* from Bürg and Mandl (2005) focuses on the learner's assessment of whether the design is conducive to learning. Additionally, to examine the participants' motivation to use the TTE further, we added the questionnaire *Perception of Importance* from Prenzel and colleagues (1996), where learners can report the perceived importance of the TTE for exams, seminars, education, and future life.

Table 4. Scales for Measuring User Experience After Learning with the Toolbox Teacher Education

Scale	Cronbach's α	No. Items	Scale	Item Example
Unified Theory of Acceptance and Use of Technology (UTAUT)	0.89	4	5-point	*The TTE is a valuable learning tool for my studies*
Perceived Website Usability – German (PWU-G)	0.95	7	7-point	*I can quickly find the information I am looking for*
Medial Design	0.90	5	5-point	*The design was helpful for learning*
Perception of Importance	0.87	5	5-point	*Learning with the TTE is important for my further education*

4. Results

4.1 Seminar 1

We conducted paired-samples t-tests for each topic (see Table 5). Results show almost consistently significant learning gains and middle to high effect sizes, except for motivational activation, difficulty level 3. The highest learning gain can be seen for the topic digital media, difficulty level 2 (a 140.19% increase). For this topic, the task differed from the other three tasks (the participants must find a digital tool that could support a lesson instead of writing a summary). The lowest learning gain was achieved for motivational activation, difficulty level 3 (a 3.45% increase).

Table 5. Results of Paired-Samples t-Tests for Seminar 1, Calculated for Each Topic Separately

Topic	No. items	Difficulty Level	Max. score	Pretest		Posttest		*t*(26)	*p*	Cohen's *d*
				M	*SD*	*M*	*SD*			
Motivational Activation	4	1	20	6.37	4.23	12.56	3.13	6.852	< .001	1.319
	3	2	15	7.07	2.51	9.11	2.42	4.012	< .001	0.772
	3	3	15	9.85	2.66	10.19	2.08	0.595	.557	0.115
Feedback	4	1	19	9.91	2.99	13.52	2.47	7.291	< .001	1.403
	4	2	18	12.52	2.91	14.56	1.48	3.788	< .001	0.729
	4	3	19	12.52	2.74	14.37	2.19	3.312	.003	0.637
Heterogeneity	4	1	20	10.56	2.93	13.59	1.91	4.332	< .001	0.834
	4	2	20	11.44	3.49	13.22	2.55	2.655	.013	0.511
	4	3	18	7.33	3.28	9.44	2.41	3.363	.002	0.647
Digital Media	4	1	20	4.74	3.38	11.04	4.65	6.053	< .001	1.165
	4	2	20	5.15	2.21	12.37	2.84	16.021	< .001	3.083
	3	3	14	6.67	1.33	7.52	1.01	2.791	.010	0.537

Note. $n = 27$.

For the topics feedback, heterogeneity, and digital media, consistently significant learning gains and middle to high effect sizes can be found for each difficulty level ($0.51 \leq d \leq 3.08$). Prior knowledge is overall relatively high (percentage of correctness for motivational activation, range: 31.85–65.67%; feedback, range: 52.16–69.56%; heterogeneity, range: 40.72–57.20%; and digital media, range: 23.70–47.64%). However, a consistently significant learning gain can be analyzed for these topics. Consequently, participants learned successfully despite high prior knowledge.

Standard deviations are, especially in the pretest, relatively high. Because the pretest included all questionnaires about all four topics, the overall questionnaire was quite long: the mean duration to complete the pretest was 25.90 minutes, probably resulting in concentration difficulties or sloppiness. Therefore, we analyzed correlations between the duration and pretest scores, but no meaningful correlation coefficient could be found.

The participants stated above-average results for all SRL scales: goal setting, planning, self-efficacy, and self-motivation (range: 2.74–3.24 on a 4-point Likert scale). Moreover, all scales show good reliability values (see Table 6). The highest values were reported for self-motivation and the lowest for planning.

Table 6. Descriptive Data for the Self-Regulated Learning (SRL) Scale of Seminar 1

Scale	*M*	*SD*	Min	Max	Cronbach's α
Goal Setting	3.148	0.629	2	4	0.813
Planning	2.740	0.778	1.2	4	0.859
Self-efficacy	2.978	0.527	2	4	0.789
Self-motivation	3.235	0.538	2	4	0.738

Note. n = 27.

4-point Forced Likert Scale.

1 = not true at all, 4 = totally true.

To answer RQ2, we correlated the reported values of the SRL scales and the pre- (prior knowledge) and posttest (learning performance) values from the knowledge tests. A correlation pattern can be seen for the SRL scales goal setting, planning, self-efficacy, and prior knowledge for the topic feedback. Moreover, the scales of goal setting and planning correlate with the prior knowledge of motivational activation, and digital media (see Table 7). Although we found some significant correlations, no systematical or meaningful pattern can be shown (see Table 7).

Table 7. Pearson Correlations for Self-Regulated Learning (SRL) and Learning Performance for Seminar 1

	Topic	Difficulty Level	SRL Sales			
Pretest values			goal setting	planning	self-efficacy	self-motivation
	Motivational Activation	3	n.s.	.405*	n.s.	n.s.
	Motivational Activation	1 + 2	n.s.	n.s.	n.s.	n.s.
	Feedback	1	.399*	.389*	.447*	n.s.
	Feedback	2 + 3	n.s.	n.s.	n.s.	n.s.
	Heterogeneity	1 + 2 + 3	n.s.	n.s.	n.s.	n.s.
	Digital Media	1	.421*	n.s.	n.s.	n.s.
	Digital Media	2 + 3	n.s.	n.s.	n.s.	n.s.
Posttest values			goal setting	planning	self-efficacy	self-motivation
	Motivational Activation	3	n.s.	n.s.	n.s.	.476*
	Motivational Activation	1 + 2	n.s.	n.s.	n.s.	n.s.
	Feedback	1 + 2 + 3	n.s.	n.s.	n.s.	n.s.
	Heterogeneity	2	n.s.	n.s.	.433*	n.s.
	Heterogeneity	1 + 3	n.s.	n.s.	n.s.	n.s.
	Digital Media	1 + 2 + 3	n.s.	n.s.	n.s.	n.s.

Note. n = 27.

2-tailed, $^{**}p > .01$, $^{*}p > .05$.

Only statistically significant correlation coefficients are displayed. For better clarity, the difficulty levels would be pooled if all correlations were not statistically significant.

Subsequently, we wanted to explore how the participants assessed the UX of the TTE during self-study phases (RQ3).

Table 8 shows descriptive data for the UX scales. The means are at least above 52.78% of a scale's minimum, concluding that the scores are consistently in the upper half. Therefore, the participants rated the TTE outstandingly well (see Table 8).

However, because the sample size is small, these results are preliminary and serve as a trend line. Moreover, it can be assumed that only participants who liked the TTE took time after the seminar to complete the questionnaire. Therefore, we did not analyze the correlations between learning performance and UX further.

Table 8. Descriptive Data for User Experience Scales of Seminar 1

Scale	*M*	*SD*	Min	Max	Cronbach's α
Unified Theory of Acceptance and Use of Technology (UTAUT)	3.275	0.996	1.75	5	0.920
Perceived Website Usability (PWU)	6.0	0.628	5.29	7	0.886
Medial Design	4.340	0.499	3.60	5	0.740
Perception of Importance	3.840	0.540	3.00	4.8	0.484

Note. $N = 10$.

Maximal value: UTAUT = 5; PWU = 7; Medial Design = 5; Perception of Importance = 5.

4.2 Seminar 2

According to Seminar 1, we first analyzed the data of the knowledge tests to investigate whether the usage of the TTE led to a significant learning gain in an FC teaching method. To answer the RQ1, we conducted paired-samples t-tests for each topic separately (see Table 9). Results show a highly significant learning gain (p <.001), without exception, and middle to high effect sizes ($0.51 \leq d \leq 2.26$).

The highest learning gain was found for motivational activation, difficulty level 1 (100.66% increase). Here, the lowest prior knowledge (37.90% correctness) and the highest learning gain (7.63) can be found. The lowest learning gain showed for scaffolding on difficulty level 3 (11.20% increase).

Table 9. Results of Paired-Samples t-Tests for Seminar 2, Calculated for Each Topic Separately

Topic	No. items	Diff. Level	Max. score	Pretest		Posttest		*t*	*df*	*p*	Cohen's *d*
				M	*SD*	*M*	*SD*				
Motivational Activation	4	1	20	7.58	1.43	15.21	2.95	18.52		< .001	2.26
	3	2	15	6.48	1.25	10.52	1.97	15.56	66	< .001	1.9
	3	3	15	9.24	1.77	11.25	1.71	7.99		< .001	1.0
Heterogeneity	4	1	20	12.30	2.75	16.92	2.48	11.6		< .001	1.44
	4	2	20	9.65	3.14	14.29	2.63	10.07	64	< .001	1.25
	4	3	28	11.78	3.94	14.23	2.40	5.14		< .001	0.64
Scaffolding	4	1	19	12.08	2.15	14.20	2.39	5.51		< .001	0.94
	4	2	20	11.79	2.64	13.24	2.69	4.14	65	< .001	0.51
	3	3	20	12.14	2.01	13.50	1.83	4.59		< .001	0.57
Feedback	4	1	19	10.39	3.94	15.18	2.23	8.53		< .001	1.13
	4	2	18	13.24	2.38	14.81	1.41	4.62	56	< .001	0.61
	4	3	19	14.02	2.49	15.74	1.79	4.36		< .001	0.58

Note. Motivational Activation $n = 67$.

Heterogeneity $n = 65$.

Scaffolding $n = 66$.

Feedback $n = 57$.

Similar to Seminar 1, the prior knowledge is rather high for each topic (learning performance for motivational activation, range: 37.90–61.60%; heterogeneity, range: 42.07–61.50%; scaffolding, range: 58.95–63.58%; and feedback, range: 54.68–73.79% correct answers). However, throughout, a learning gain can be measured despite high prior knowledge. Compared to Seminar 1, a significant learning gain can be measured for motivational activation, difficulty level 3. Moreover, the prior knowledge is lower than for Seminar 1. For the topics feedback, heterogeneity, and motivational activation, a higher learning gain can be measured for Seminar 2 compared to Seminar 1.

Regarding SRL, the participants reported above-average skills (2.70–3.20 on a 4-point Likert scale). Equally to Seminar 1, the highest value can be seen for self-motivation and the lowest for planning. Additionally, we obtained good reliability values (see Table 10).

Table 10. Descriptive Data for the Self-Regulated Learning Scale From Seminar 2

Scale	*M*	*SD*	Min	Max	Cronbach's α
Goal setting	3.051	0.749	1.25	4	0.843
Planning	2.701	0.736	1	4	0.861
Self-efficacy	2.989	0.547	2	4	0.829
Self-motivation	3.201	0.590	1.67	4	0.722

Note. *N* = 73.

4-point Forced Likert Scale.

1 = not true at all, 4 = totally true.

To address RQ2, we correlated the SRL scales with prior knowledge (pretest) and learning performance (posttest). A prominent pattern was found in the posttest data. Here, goal setting, planning, and self-efficacy scales correlated significantly with the learning performance for feedback (see Table 11). Similar to Seminar 1, significant individual correlations can be found, but no meaningful interpretation can be provided.

Table 11. Pearson Correlations for Self-Regulated Learning (SRL) and Learning Performance for Seminar 2

	Topic	Difficulty Level	SRL Scales			
Pretest values			goal setting	planning	self-efficacy	self-motivation
	Motivational Activation	1	n.s.	n.s.	n.s.	.266*
	Motivational Activation	2 + 3	n.s.	n.s.	n.s.	n.s.
	Heterogeneity	1 + 3	n.s.	n.s.	n.s.	n.s.
	Heterogeneity	2	n.s.	-.268*	n.s.	n.s.
	Scaffolding	1	n.s.	n.s.	n.s.	n.s.
	Scaffolding	2	.259*	n.s.	n.s.	n.s.
	Scaffolding	3	.423**	n.s.	n.s.	n.s.
	Feedback	1 + 2 + 3	n.s.	n.s.	n.s.	n.s.
Posttest values			goal setting	planning	self-efficacy	self-motivation
	Motivational Activation	1 + 3	n.s.	n.s.	n.s.	n.s.
	Motivational Activation	2	.281*	.297*	.245*	n.s.
	Heterogeneity	1 + 2 + 3	n.s.	n.s.	n.s.	n.s.
	Scaffolding	1 + 2 + 3	n.s.	n.s.	n.s.	n.s.
	Feedback	1 + 2 + 3	n.s.	n.s.	n.s.	n.s.

Note. *n* = 27.

2-tailed, ***p* > .01, **p* > .05.

Only statistically significant correlation coefficients are displayed. For better clarity, the difficulty levels would be pooled if all correlations were not statistically significant.

To answer RQ3, we analyzed, like Seminar 1, the UX questionnaires. Consistently, the participants rated the TTE above average (≥ 59.93%; see Table 12). Consequently, we could replicate the findings from Seminar 1 with a more significant sample ($N = 61$). The highest score was reported for perception of importance (82.16%). Therefore, the TTE was perceived as helpful for further education. A significant correlation between the learning performance for difficulty level 3, topic feedback, and PWU could be found ($r = 0.30$; $p = .032$).

Table 12. Descriptive Data for User Experience Scales From Seminar 2

Scale	*M*	*SD*	Min	Max	Cronbach's α
Unified Theory of Acceptance and Use of Technology (UTAUT)	3.529	.873	1	5	0.872
Perceived Website Usability (PWU)	5.487	1.254	2.14	7	0.959
Medial Design	4.082	0.767	1.60	5	0.901
Perception of Importance	4.108	0.773	1.60	5	0.872

Note. $N = 61$.
Maximal value: UTAUT = 5; PWU = 7; Medial Design = 5; Perception of Importance = 5.

5. Discussion, Limitations, and Conclusion

Because current research shows that the FC approach promotes learning (see van Alten et al., 2019), it is worthwhile to apply this approach and include self-studying phases with additional lectures for in-depth discussions. We wanted to know whether an FC can successfully and feasibly be integrated into an authentic teaching setting. Therefore, we evaluated two university seminars over an entire semester, designed as an FC, and used an open educational resource as material for self-studying. We measured prior knowledge, learning performance, SRL, and how usable the TTE was for participants.

5.1 The FC Approach and the Impact on Learning Gain (RQ1)

Our findings show that the FC design and the TTE as material for self-studying lead to significant learning gains with medium to high effect sizes in both seminars (see Tables 5 and 9). Only in Seminar 1 no significant increase could be measured for the topic motivational activation, difficulty level 3. An explanation could be the high prior knowledge for this section. Moreover, the topic motivational activation is easy to understand, and the questions can be answered intuitively (e.g., *A math teacher states the following "I give girls easier tasks so they have a sense of accomplishment and I can praise them when they get something right." Which statements are true?*).

Also, the delay of the posttest could have contributed to the nonsignificant learning gain for difficulty level 3 (see Figure 1). Moreover, the self-study phase was the first where participants studied with the TTE. Exploring and orienting in the new learning platform probably caused additional cognitive load.

The topic digital media, difficulty level 2, in Seminar 1, showed the highest learning gain (see Table 5). Here, the participants introduced a beneficial media tool. Perhaps the participants prepared more intensively for this task because they had to present the tool in front of the class. Nevertheless, the topic of digital media was the last one before the posttest and was cognitively more available than the other topics. Results from Seminar 2 show higher significant gains throughout, compared to Seminar 1, and middle to high effect sizes (see Table 9).

We measured a general high prior knowledge in both seminars and significant learning gains. Additionally, a learning increase can be measured for the nonsignificant result in Seminar 1. As a result, the TTE is suitable for every level of knowledge in higher education.

We classified the questionnaire into three ascending difficulty levels (see Table 2). It would be reasonable that the most challenging questions are more complex and lead to a lower score than the simple questions. However, our results also show high scores on difficulty level 3 (see Tables 5 and 9). Because the questions with difficulty level 3 presented the most information in context, it is likely to assume that the context helped students answer the question correctly (response selection; see Moosbrugger & Kelava, 2012).

Notable are the differences between the seminars. Seminar 1 included face-to-face lectures, whereas Seminar 2 was, due to the pandemic, exclusively online. Moreover, the placement of the posttest(s) differed: in Seminar 1, the posttest was at the end of the semester and included all topics at once, which could have affected the measurement of learning (e.g., primacy and recency effects or short- and long-term-effects; Deese & Kaufman, 1957; Murdock, 1962).

To avoid this measurement error, we divided the questionnaires by topics and added the posttest after each lecture in Seminar 2. Thus, the questionnaires were shorter and measured the level of knowledge immediately. Moreover, this approach offered time to include the questionnaire about UX in the last online meeting, resulting in a larger and more reliable sample than in Seminar 1, where the questionnaire about UX needed to be completed after the lecture (see Figure 1).

5.2 SRL and the Influence on Learning Performance (RQ2)

Regarding SRL, the participants of both seminars reported above-average SRL scores (see Tables 6 and 10). Consequently, the participants perceived their forethought for self-studying as good or very good. Another commonality between both seminars is that self-motivation showed the highest and planning the lowest score on the SRL scales. As a result, the participants were motivated but not outstandingly organized while learning.

Although we could not find significant relations between the reported SRL and learning performance (see Table 11). We used the subscale forethought from the SRL questionnaire from Dörrenbächer and Perels (2016), which measures goal setting, planning, self-efficacy, and self-motivation (see Table 3). However, these concepts could not have been as meaningful for measuring the SRL skills during the self-study phases.

Contingently, other subscales (e.g., performance or reflection) would have given a better picture of how the participants monitor and regulate their learning strategies during learning, which probably would show correlations with learning performance. Nevertheless, we can assume that the SRL skills promoted learning due to the successful knowledge increase. Future research should consider if the FC improved the SRL skills of the participants by using the reflection or performance subscales in a pre- and posttest design (see Lai & Hwang, 2016).

5.3 The Learner's Assessment of the UX of the TTE (RQ3)

The participants from both seminars assessed the TTE as usable and well-designed and as an important tool for learning (see Tables 8 and 12). Results from Seminar 1 could be replicated with a more significant sample from Seminar 2. Due to a time constraint in Seminar 1, the questionnaire about UX needed to be filled in after the last face-to-face session, resulting in a small remaining sample (N = 10; see Figure 1 and Table 1). Additionally, we assumed that only participants who liked the TTE completed the questionnaire, which could have led to a measurement bias.

Therefore, we used the UX results from Seminar 1 as a trend line. The more reliable sample from Seminar 2 replicated the findings from Seminar 1. Unfortunately, we could not find a systematic correlation between learning performance and UX. Similar to the results of SRL, we can draw an indirect connection between successful learning and a positive UX because of the significant learning gain. However, the TTE can be seen as a valuable tool for the FC approach.

A limitation and a benefit at the same time is that we carried out some field research. On the one side, it is limited to controlling what and how the participants learn at home. On the other, it is an authentic setting and a measurement of actual conditions, providing high ecological validity. This issue goes hand in hand with whether the TTE contributes solely to the significant learning gain or if the participants consulted other materials (e.g., articles, other platforms, or websites) during self-studying.

However, the concern about where exactly the participants' knowledge comes from (articles, TTE, other platform, other websites) remains while doing field research. The missing control group (e.g., traditional lectures) may be seen as a limitation. Yet, our work aims to show a feasible example of implementing a CBLE in an FC, which we have successfully accomplished based on our results.

In conclusion, we showed in two seminars that the FC approach leads to a significant learning gain. Moreover, based on our findings and expertise, we demonstrated that the TTE, as a representation of CBLEs and an open educational resource, is suitable for self-studying and supports the FC approach. Therefore, we presented a realizable FC approach, which can be seen as an application example because the TTE is an open educational resource that can be integrated flexibly into university seminars depending on the needs of learners, lecturers, and the design of the seminar.

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