Evaluation of four digital tools and their impact on active learning, repetition and feedback in a large university class

Dorothee C. Tautz

School of Applied Psychology

University of Applied Sciences and Arts Northwestern Switzerland (FHNW)

Olten, Switzerland

Abstract

Large university classes often face challenges in enhancing active learning, repetition and feedback in the classroom which are essential for promoting student learning. The purpose of this study is to investigate if digital tools can be a solution. It evaluates how students perceive four digital tools (Lecture Recordings, Question Tool, Classroom Response System and Virtual Reality) in a large lecture class and examines to what extent the tools have an impact on active learning, repetition and feedback. The study applied a mixed methods design and collected data from a survey (95 participants) and focus groups (11 participants). Participants were students from a psychology class. The results show that students enjoyed using the tools because they brought variety to the lecture. However, students perceived differences in the tools' impact on active learning, repetition and feedback. The impact of CRS and Lecture Recording were rated rather high whereas impacts of Question Tool and VR modules were rated lower. The study revealed that key aspects for students' perception of tools are the way tools are integrated in the classroom and how much time they consume during the lecture.

Keywords: digital tools, higher education, technology-enhanced learning, active learning, repetition, feedback

Zusammenfassung

Grosslehrveranstaltungen stehen oft vor der Herausforderung, aktives Lernen, Wiederholung und Feedback im Unterricht zu fördern. Das Ziel dieser Studie ist es, herauszufinden, ob digitale Tools eine Lösung sein können. Sie untersucht, den Einsatz von vier digitalen Tools (Vorlesungsaufzeichnungen, Fragetool, Classroom Response System und Virtual Reality) im Unterricht und den Einfluss der Tools auf aktives Lernen, Wiederholung und Feedback. Die Studie folgt einem Mixed Methods Design und sammelte Daten anhand eines Fragebogens (95 Teilnehmer) und Fokusgruppen (11 Teilnehmer). Teilnehmer waren Psychologie-Studierende. Die Ergebnisse zeigen, dass die Studierenden die Tools gerne nutzen, da sie eine Abwechslung bieten. Allerdings nahmen sie auch Unterschiede zwischen den Tools hinsichtlich des Einflusses auf aktives Lernen, Wiederholung und Feedback wahr. Am höchsten wurde der Einfluss des CRS und der Vorlesungsaufzeichnungen bewertet, wohingegen das Fragetool und Virtual Reality einen geringeren Einfluss hatten. Die Studie zeigt, dass es für die Bewertung der Tools durch die Studierenden eine Rolle spielt, wie die Tools eingesetzt werden und wie viel Zeit sie im Unterricht einnehmen.

Keywords: digitale Tools, Hochschulausbildung, technologiegefördertes Lernen, aktives Lernen, Wiederholung, Feedback

Evaluation of four digital tools and their impact on active learning, repetition and feedback in a large university class

Effective learning and teaching can be a challenge in traditional large lecture classes (Yang et al., 2018), which usually consist of 100-150 students (Denker, 2013) and include a lecturer who directly communicates lecture's contents to the students (Lambert, 2012). Students listen passively and absorb the new information presented by the lecturer (Mayer et al., 2009). There are several reasons why traditional large lecture classes face challenges and why they bring some disadvantages regarding effective learning and teaching. One reason is that they often fail in encouraging student engagement and that they promote passive and superficial learning (Bransford et al., 2000). Students often lack the possibility to participate in the lecture and lecturers cannot interact with all students individually due to time and organizational reasons (Yang et al., 2018). It is also difficult to integrate active learning, repetition and feedback in the lecture which are important factors for students' learning (Schneider & Preckel, 2017). An active learning environment is important because it increases students' attention and engagement (Kay et al., 2019). They are encouraged to think actively about the lecture's contents rather than just passively listening (Bonwell & Eison, 1991). Repetition is another essential factor because students need the possibility to repeat lectures' contents to understand and memorize the new information (Dahlin & Watkins, 2000). In addition, regular feedback is needed because it enables students to monitor their learning progress and to discover knowledge gaps (Hattie & Timperley, 2007). Digital tools implemented in the lecture can be a solution to promote active learning, repetition and feedback in the classroom. They also increase active participation (Bilyalova et al., 2019), learning motivation and learning outcomes (Lin et al., 2017). Moreover, students use the tools individually so that all of them can take part. Based on these findings, the purpose of this

study is to evaluate four digital tools in a large lecture class and to examine the effects of the tools on active learning, repetition and feedback. The four examined digital tools are Lecture Recordings, a Question Tool, a Classroom Response System (CRS) and Virtual Reality (VR) modules.

Lecture Recordings are recordings of the screen of the lecturer including audio commentary (Gilardi et al., 2015). The recordings are uploaded on an online platform so that students have always access to repeat the lecture. Universities increasingly record lectures and make them online available for students (Bos et al., 2016). Students enjoy using lecture recordings due to several benefits. They are useful for revision, preparing for the exam, catching-up on missed lectures and taking notes at own pace (Copley, 2007). Recordings also increase exam performance (Abdous et al., 2012; Bos et al., 2016; Luttenberger et al., 2018; Nordmann et al., 2019) and offer flexibility about where and when students can listen to them.

The *Question Tool* is a communication tool, which students use during class. Students have the possibility to ask questions anonymously by entering them in a chat window with their smartphone or laptop. Lecturers see all questions on their screen and answer them in class. This tool benefits especially students who are too shy to interrupt the lecture by asking questions (Gan & Balakrishnan, 2016; Montgomery et al., 2019). It also increases participation (Montgomery et al., 2019) and improves interaction between students and lecturer (Palinko et al., 2018).

The *Classroom Response System (CRS)* is an interactive electronic quiz tool (Castillo-Manzano et al., 2016). Lecturers present multiple-choice or single-choice questions on their computer projector and students answer them individually on their smartphone or laptop. Afterwards, overall results are presented in class and lecturer explains the correct answer. Of all four digital tools evaluated in this paper the CRS was most investigated in the past by other

researchers. There have been several meta-analysis measuring the effects of CRS (Castillo-Manzano et al., 2016; Chien et al., 2016; Hunsu et al., 2016; Wood & Shirazi, 2020). Advantages of CRS are among others that it increases fun, attention, participation and classroom dynamics in the lecture (López-Quintero et al., 2016) and that it enriches quality of student learning (Licorish et al., 2018). Student also receive instant feedback on their performance (Ludvigsen et al., 2015; Wood & Shirazi, 2020) and improve their academic achievements (Ma et al., 2018).

Virtual Reality (VR) is a technology that uses computer hardware and software to create an artificial environment, which is similar to the real world (Alfalah et al., 2017). These virtual worlds are three-dimensional simulated environments (Chalil Madathil & Greenstein, 2017). Users interact with the artificially generated environment and experience real world situations (Riener & Harders, 2012). They are able to look around the artificial world, move around in it, and interact with virtual features or items (Fabris et al., 2019). In the last few years, the integration of virtual reality environments in education processes became quite popular and the interest of researchers grew (Fabris et al., 2019). However, there is still a lack of research that focuses on the learning outcomes of VR and that applies VR in actual teaching (Radianti et al., 2020). Only few studies reported positive impacts of using VR in class like an increase in motivation (Villena Taranilla et al., 2019) and improved student performance (Ray & Deb, 2016).

Theoretical background

Active Learning

Active Learning is a very broad investigated construct in education. Already in 1987 Chickering & Gamson developed seven principles for good educational practice and included active learning as one of their principles. Despite this, there is no common, clear definition of

active learning because among the term active learning falls a variety of activities, instructions and interpretations (Freeman et al., 2014; Prince, 2004). The current literature provides some core elements that are associated with active learning. It refers to activities that take place in the classroom (Prince, 2004) and occurs when instructors integrate students directly into the class using exercises to apply newly acquired knowledge (Silberman, 1996). The purpose of introducing activities is to promote student activity and engagement in the learning process (Prince, 2004) and to encourage students to think about what they are doing (Bonwell & Eison, 1991). Less emphasis is placed on passive transmitting and receiving information and more on developing student skills and student exploration (Bonwell & Eison, 1991; Kim et al., 2013). Moreover, research has demonstrated that active learning methods facilitate learning (Broadbent & Poon, 2015; Han et al., 2015) and increase student performance (Freeman et al., 2014). In a traditional large lecture class, active learning often comes up short because lecturers have difficulties in integrating all students into the lecture and in giving them enough possibilities to participate and to apply their knowledge (Gan & Balakrishnan, 2016; Montgomery et al., 2019). Consequently, knowledge gaps and ambiguities remain undiscovered. Based on the literature, which is presented in the following, it can be assumed that the Question Tool, CRS and VR modules can support active learning in the classroom. Regarding the Question Tool, Palinko et al. (2018) found that students asked a lot more questions when using a Question Tool compared to raising hands and that activity and understanding of course content increased. Looi et al. (2010) discovered that Question Tools have the potential to create a flexible learning environment and to transform the lecture from teacher-centered to an active student-centered learning environment. Regarding the CRS, empirical research shows that the tool is suitable for promoting active learning in the classroom (Coca & Slisko, 2017; Heaslip et al., 2014;

Stanojević & Ranđelović, 2018). Students are encouraged to actively participate, be more attentive and think about the multiple-choice questions (Stanojević & Ranđelović, 2018). Moreover, CRS supports comprehension of the course' contents (Fuad et al., 2018) and since the CRS is used independently, it also offers all students the opportunity to participate (Heaslip et al., 2014). It can also be assumed that VR environments promote active learning because they encourage learning by doing (Radianti et al., 2020) and exploring the virtual world (Fabris et al., 2019). Empirical research in the past has shown that Virtual Reality environments increase motivation, engagement (Villena Taranilla et al., 2019) and enjoyment (Maresky et al., 2019), which are essential aspects of active learning.

Repetition

Empirical research has proofed that repetition is beneficial for learning (Cepeda et al., 2008; Dahlin & Watkins, 2000; Rawson & Dunlosky, 2011). It is necessary to achieve proficiency (Thalheimer, 2006) and is positively linked with final exam performance (Andergassen et al., 2014). Ebbinghaus (1885) investigated the positive effects of repetition on learning already in 1885. He developed the so-called "forgetting curve", which says that information is forgotten over time and that it does not remain in the memory. This effect can be flattened by regular repetition of the stimulus. Moreover, Dahlin and Watkins (2000) defined two purposes of repetition. First, repetition creates a deep impression of the new information so that the information are engraved more deeply in the memory and second, a new understanding for the learned information is created and new meaning discovered. Repetition can also take place in different modalities (visual, auditory, olfactory, kinesthetic) and through different learning media (text, audio, video, computer, internet) (Thalheimer, 2006). Based on the empirical research it can be assumed that Lecture Recordings and CRS promote repetition in the classroom. Recent

studies have shown that if lecture recordings are available, the majority of students uses them to repeat lectures' contents and to deepen their knowledge (Ebbert & Dutke, 2020; Morris et al., 2019). Using the CRS is also positively correlated with repetition in the classroom (Collier & Kawash, 2017; Combes, 2019). Repeating contents by answering multiple-choice questions strengthens their knowledge and allows information to be transmitted to the long-term memory (Collier & Kawash, 2017).

Feedback

Feedback in the classroom is an essential factor to promote learning and academic achievement (Evans, 2013; Hattie & Timperley, 2007; Schneider & Preckel, 2017). Feedback is a process during which students receive information on their current performance and understanding. It provides them the opportunity to monitor their learning progress, to recognize their strengths and weaknesses and to see what they need to focus on (Sadler, 1989). This is important to close the gap between current and desired understanding (Hattie & Timperley, 2007; Sadler, 1989). The process of feedback can be differentiated in three steps, which need to be satisfied simultaneously to create effective feedback for the students. First, students need to know what the standard or goal is they are heading for. Secondly, they need information to compare their current level of performance with the norm or target and thirdly, students need to know what steps they need to take to improve their performance and to get closer to the expected goal (Hattie & Timperley, 2007; Sadler, 1989). In traditional large lecture classes, it is often difficult to provide feedback for all students due to a lack of interactivity between students and lecturer (Yang et al., 2018). The CRS and Question Tool can be a solution here because they have the potential to deliver individual feedback to all students. When using CRS during the lecture, students receive rapid feedback on their responses. This helps them to monitor their

learning progress and to identify knowledge gaps (Ismaile & Alhosban, 2018; López-Quintero et al., 2016). Using the Question Tool provides students with relevant feedback on what they have not understood so far. They also have the possibility to check if they understand questions asked by others and to compare their understanding with the other students (Montgomery et al., 2019; So, 2016).

Purpose of the study and research questions

The purpose of this study is to investigate how students perceive the above-mentioned four digital tools and their implementation in a large lecture class. It also examines to what extent digital tools differ in their impact on active learning, repetition and feedback to make assumptions which tools fit best for increasing either one of the three factors. Finally, ideas for improving and developing the tools and their implementation are derived. The following research questions arise from that:

1. How do students perceive the Lecture Recordings, the Question Tool, the CRS and VR modules and their implementation in class?
2. How do students perceive the impact of Lecture Recordings, Question Tool, CRS and VR modules on active learning, repetition and feedback? To what extent differ the tools in their impact?
3. How can digital tools and their implementation be further optimized and developed for future use?

Context of the study

The study was conducted with first-year psychology students (bachelor degree) who took part in the course “General Psychology I” during the fall semester 2019. The course consisted of 12 lectures (3 x 45 min) during which students used the four digital. In the first lecture, the four

tools were introduced to the students. From then on, every lecture was recorded and uploaded so that students could watch the Lecture Recordings during their free time. The Question Tool and CRS were implemented into each lecture. Both are web applications, which students used with their smartphone or laptop. The Question Tool was started at the beginning of the lecture so that students could enter their questions anonymously during the lecture. Questions of the other students were not visible. The lecturer collected all incoming questions and after about 45 minutes, all questions received up to that point were answered. The CRS was used at the beginning of the lecture. Students answered three single-choice questions, which were constructed according to the first three levels of Bloom's Taxonomy: Knowledge, Comprehension and Application (Bloom, 1956). Overall results were shared on screen and lecturer explained the correct answer when more than 20 % answered incorrectly or when students asked for it. During the fifth lecture, the first VR module was deployed using Google Cardboard and WebVR. Students used their own smartphones and received the cardboard from the lecturer. Via a QR-Code, they opened the VR modules with their smartphone and inserted it into the cardboard. The first VR module dealt with color perception, which was also the topic of the lecture. After the lecture, students had the possibility to complete two more modules dealing with distance perception voluntarily at home. In the seventh lecture, another VR module was conducted during the lecture dealing with observer effects in an interview.

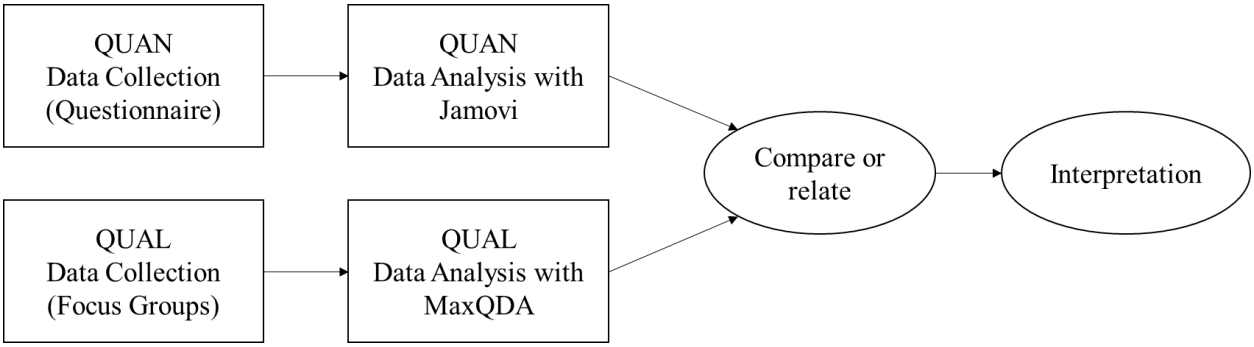
Study Design

The study design is based on a pragmatic world view, which is characterized by a research problem that is in the center of the study and all sorts of approaches that are used to understand the problem. Researchers do not focus on a particular method but are free to choose any method, technique or procedure that suits to answer the research questions (Creswell &

Creswell, 2018). In this study, a Convergent Mixed Methods Design was applied to answer the research questions (see Fig. 1). In this design, both quantitative and qualitative data are collected and analyzed separately and results are integrated during the discussion using a side-by-side approach (Creswell & Creswell, 2018). The different methods benefit from complementary strengths and neutralize weaknesses (Creswell & Creswell, 2018; Morse & Niehaus, 2016). A Convergent Mixed Methods Design was chosen because one method alone was insufficient to address the study's research purpose. A combination of quantitative and qualitative provides a more comprehensive analysis of the research problem and results in a better understanding (Clark & Ivankova, 2015). In addition, the parallel design ensures that data collection and analysis do not influence each other. A survey was used to collect quantitative data. The survey delivers generalisable information on how students perceive the impact of the tools on active learning, repetition and feedback, and integrates all students of the course. But, it does not collect any in-depth information on what students liked or disliked about the tools and how they and their implementation can be improved. That's why qualitative data are necessary. In this study qualitative data are collected with focus groups. Focus groups are group discussions with several participants, which reveal in-depth information and encourage participants to think critically and in-detail about the topic. During the discussion part of this study, both data sets are integrated using a side-by-side approach and compared to identify similarities and contradictions (Creswell & Creswell, 2018).

Figure 1

Convergent Design (Creswell & Creswell, 2018)



Study 1

Method

Procedure and Sample

At the end of the semester during the 12th lecture an online survey was conducted. It was a live survey and all students present in the lecture were asked to participate. Completing the questionnaire was voluntary and took around 10 minutes. The questionnaire consisted of four parts. Each part contained the same items to assess active learning, repetition and feedback but was related to another digital tool. Students were asked to complete all four parts so that the results for the different tools could be compared during the analysis. To receive a representative result for all students attending the course, the sample size should be above 92 participants (when applying a confidence interval of 95 % and 5 % margin of error). 99 students were present during the lecture and started the questionnaire. From these 99 students, 95 answered the questionnaire completely (N_{male} = 19 / N_{female} = 76). Only completely answered questionnaires were used for the analysis.

Measures

The purpose of the quantitative study was to collect data about how students perceive the tools' impact on active learning, repetition and feedback and to compare results. A questionnaire was used because it entails several advantages. It offers the opportunity to get an overview of the opinions of all participants and provides generalizable information (Blair et al., 2014). The questionnaire used in this study was developed in line with current standards and guidelines of the APA for creating surveys (AERA, APA & NCME, 2014). In the first step, a thorough literature research of the three constructs was conducted. Based on the findings, items were developed for each construct. In the next phase, the initial item list was discussed with two experts. During the discussion, the items were reviewed, sharpened and adjusted. Those discussion rounds took place multiple times until the questionnaire was finished. In the last step, a pilot took place to test the comprehensibility of the questionnaire items. Three students took part who were familiar with the four digital tools. Based on the reactions of the pilot participants the questionnaire was again adjusted and finalized. The final questionnaire (see Table 1) consisted of six items for each construct using a 7-point Likert Scale with a response format from 1 (very unlikely) to 7 (very likely).

Data Analysis

The collected data were analyzed with Jamovi. The analysis included a confirmatory factor analysis, reliability analysis and a one-way repeated measures analysis of variance (ANOVA).

Table 1

Items of the survey

Construct	Item
Active Learning	Using the "tool" in this lecture encouraged me to ask questions during the lecture. (Q1) By using the "tool" in this lecture I was more active in the lecture. (Q2) Using the "tool" in this lecture made me explore the contents of the lecture more. (Q3) By using the "tool" in this lecture I was more attentive during the lecture. (Q4) Using the "tool" in this lecture encouraged me to think critically about what I am learning. (Q5) Using the "tool" made it easier for me to follow the lecture. (Q6)
Repetition	Using the "tools" in this lecture helped me to better memorize the content of the lecture. (Q7) Using the "tool" in this lecture helped me to repeat the content of the lecture. (Q8) Using the "tool" in this lecture made me deal more often with the topics of the lecture. (Q9) By repeating the content with the "tool" I understood the topics of the lecture better. (Q10) Repeating the content with the "tool" helped me to develop a deeper understanding of the content. (Q11) By repeating the content with the "tool" I learned something new. (Q12)
Feedback	The use of the "tools" in this lecture helped me to clarify misunderstandings. (Q13) By using the "tool" in this lecture I knew how well I mastered the content of the lecture. (Q14) By using the "tool" in this lecture I was aware of my current level of learning. (Q15) Using the "tool" in this lecture showed me what I still have to work on. (Q16) The use of the "tools" in this lecture showed me what content I need to further focus on. (Q17) The use of the "tool" in this lecture helped me to learn the content of the lecture. (Q18)

Results

Confirmatory Factor Analysis

The purpose of the confirmatory factor analysis is to test if the hypothesized model fits with the actual data (Field, 2017). For each digital tool, a confirmatory factor analysis was

calculated. First, modification indices were examined. They provide an empirical estimate of how strongly each item is associated with another construct (Hair et al., 2018). All four sets of data indicated a better fit for item Q18 with the construct repetition than feedback. This item also fits repetition in terms of content and consequently was moved. In the resulting new structure, the factor feedback consists of five items (Q13-Q17), the factor repetition of seven items (Q7-Q12, Q18) and the factor active learning as before of six items (Q1-Q6).

Table 2 displays a summary of the factor loadings with the new structure. Loadings should be at least .5 and ideally .7 or above to confirm a strong relation between constructs and item (Hair et al., 2018). Results show that all factor loading are above .5 and thus no items need to be removed.

Table 2

Factor Loadings

		Factor Loadings			
Construct	Item	Lecture Recordings	Question Tool	CRS	VR
Active Learning	Q1	.722	.768	.608	.649
	Q2	.836	.929	.75	.754
	Q3	.738	.913	.713	.906
	Q4	.883	.939	.898	.852
	Q5	.769	.801	.767	.786
	Q6	.805	.893	.839	.892
Repetition	Q7	.831	.86	.772	.793
	Q8	.88	.836	.835	.875
	Q9	.664	.85	.655	.801
	Q10	.822	.897	.633	.94
	Q11	.881	.882	.632	.95
	Q12	.63	.759	.516	.772
	Q18	.868	.855	.818	.859
Feedback	Q13	.681	.697	.69	.794
	Q14	.839	.863	.888	.945
	Q15	.818	.895	.935	.961
	Q16	.956	.95	.939	.972
	Q17	.972	.939	.913	.888

In the next step, fit measures were examined (see Table 3). They give an indication how well the theoretical measurement model and actual data fit (Hair et al., 2018). Goodness-of-fit indices can be separated into three categories: absolute fit, parsimony correction and comparative fit. Brown (2015) recommends using at least one index of each category because each type of index provides different information about the model fit. This study reports for each model the Standardized Root Mean Square Residual (SRMR) as absolute fit, the Root mean square error of approximation (RMSEA) as parsimony correction and the Comparative Fit Index (CFI) as comparative fit. Cut-off for SRMR is 0.8 or below (Hair et al., 2018), cut-off for RMSEA is 0.6 or below (Brown, 2015) and cut-off for CFI is 0.9 or above (Hair et al., 2018). The fit indices indicate that the measurement model and data collected for Lecture Recordings and CRS do not provide an acceptable fit. Data collected for the Question Tool and VR provide a modest fit as some of the examined fit indices are within cut-off values. Furthermore, all items load on their respective factors ($p < .001$).

Reliability

Cronbach's alpha examines the internal consistency or reliability of rating scales. Items of one scale should measure the same thing and thus should be correlated with one another (Cronbach, 1951). Table 4 displays the values of Cronbach's Alpha in this study. Values should exceed .7 (Nunnally, 1975). They are excellent above .9, good above .8 and acceptable above .7 (George & Mallery, 2003). The measures used in this study display good to excellent internal consistency, ranging from .862 to .956.

Table 3

Goddness-of-fit measures

				RMSEA 90&CI	
	CFI	SRMR	RMSEA	Lower	Upper
Lecture Recordings	.817	.1060	.154	.138	.171
Question Tool	.854	.0742	.157	.141	.174
CRS	.852	.0954	.125	.109	.143
VR modules	.913	.0712	.118	.101	.135

Table 4

Cronbachs Alpha, Mean and Standard Deviation

	Active Learning			Repetition			Feedback		
	Alpha	Mean	SD	Alpha	Mean	SD	Alpha	Mean	SD
Lecture Recordings	.909	3.29	1.39	.920	5.08	1.28	.935	4.92	1.32
Question Tool	.950	3.49	1.77	.947	3.61	1.63	.934	3.48	1.51
CRS	.894	3.98	1.42	.862	5.47	1.95	.935	6.04	0.89
VR	.918	3.06	1.51	.950	3.52	1.61	.956	2.56	1.27

Analysis of variance (ANOVA)

The one-way repeated measures ANOVA examines whether there is a significant main effect of the digital tools on perceived active learning, repetition and feedback (Fig. 2). Mauchly's Test of Sphericity revealed that the requirement of sphericity has not been met. Consequently, a Huynh-Feldt correction to the F-value was applied.

The results of the one-way repeated measures ANOVA showed that there is a significant main effect of digital tool (Lecture Recordings, Question Tool, CRS, VR) on active learning ($F(2.80) = 11.1$, $p < .001$, $\eta^2 = .106$). Post hoc tests (using the Holm correction to adjust p) indicated that Lecture Recordings and Question Tool do not differ significantly from each other

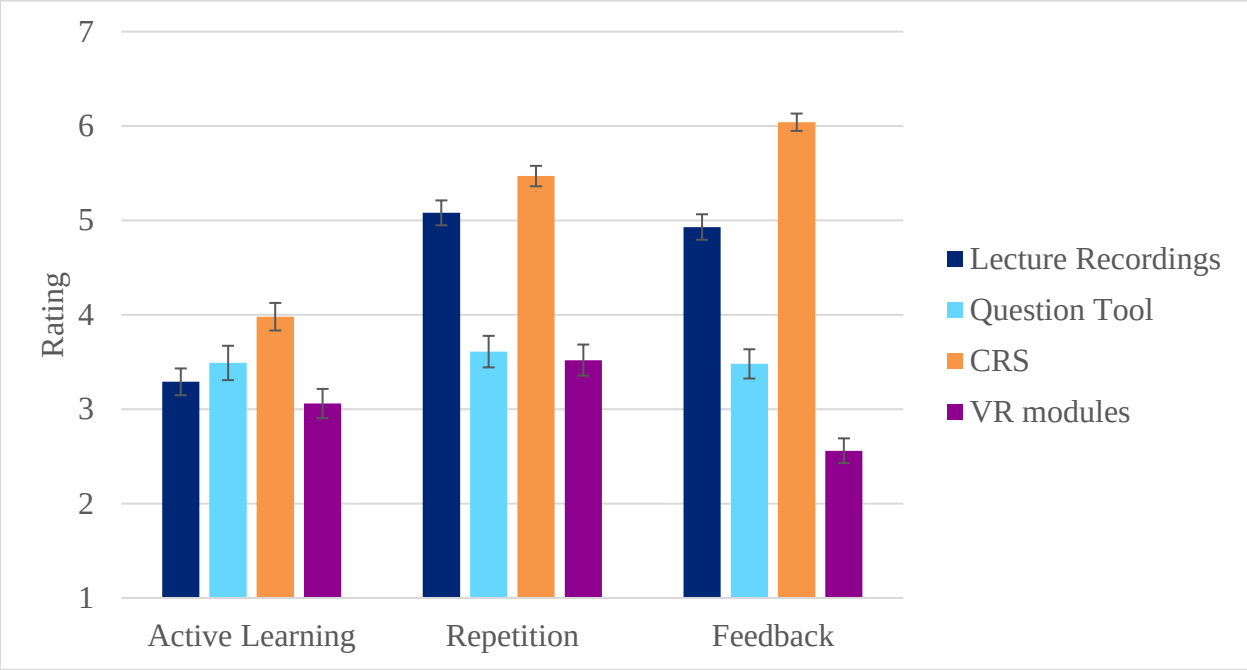
as well as Lecture Recordings and VR while all other means differ significantly from each other. Most likely CRS has a perceived impact on active learning (*M*=3.98 / *SD*=1.42) followed by the Question Tool (*M*=3.49 / *SD*=1.77). The effects of Lecture Recordings (*M*=3.29 / *SD*=1.39) and VR (*M*=3.06 / *SD*=1.51) were perceived to be less.

The results of the one-way repeated measure ANOVA also revealed a main effect of digital tool (Lecture Recordings, Question Tool, CRS, VR) on repetition ($F(2.69) = 80.5$, $p < .001$, $\eta^2 = .461$). Post hoc tests (using the Holm correction to adjust *p*) indicated that Question Tool and VR do not differ significantly from each other. All other means differ significantly from each other. Again, the perceived impact of CRS (*M*=5.49 / *SD*=1.05) on repetition was rated the highest. Followed by the Lecture Recordings (*M*=5.08 / *SD*=1.28) which lead to more repetition than Question Tool (*M*=3.55 / *SD*=1.60) and VR (*M*=3.47 / *SD*=1.59).

The results of the one-way repeated measure ANOVA also revealed a main effect of digital tool (Lecture Recordings, Question Tool, CRS, VR) on feedback ($F(2.88) = 207$, $p < .001$, $\eta^2 = .687$). Post hoc tests (using the Holm correction to adjust p) indicated that all four digital tools differed significantly from each other. CRS (*M*=6.11 / *SD*=0.871) had the highest rating and highest perceived impact on feedback followed by the Lecture Recordings (*M*=4.92 / *SD*=1.32). The impacts of Question Tool (*M*=3.53 / *SD*=1.52) and VR are rated rather low (*M*=2.43 / *SD*=1.25).

Figure 2

Ratings of active learning, repetition, and feedback for Lecture Recordings, Question Tool, CRS and VR modules



Note. Error bars are ± one standard error of the mean.

Discussion

The results of the quantitative study indicate that there are significant differences between the tools regarding their impact on active learning, repetition and feedback. Students perceived that the CRS has the highest impact on all three factors. That shows that it is well suited to enhance active learning, repetition and feedback in the classroom. In contrast to that, VR has the lowest perceived impact and it can be assumed that it is less suited to enhance active learning, repetition and feedback in the classroom. The perceived impact of all four digital tools on active learning is relatively similar and rather low compared to repetition and feedback. A reason for that could be that the implementation of a digital tool is not sufficient to create an active learning

environment. More activities need to be implemented. Comparing the four tools, the impact of CRS on active learning was rated highest. VR modules had the lowest perceived impact on active learning, which is rather surprising because VR is used actively and promotes learning by doing (Radianti et al., 2020).

Regarding repetition, there are more noticeable differences between the tools. The impact of the CRS was again rated highest, followed by the Lecture Recordings, which were slightly less but similar rated. It can be concluded, that both CRS and Lecture Recordings are well suited to enhance memorizing and understanding course contents. In comparison, the perceived effects of the Question Tool and VR modules were rated lower. These results are less surprising because the tools are rather suitable for clarifying understandings or exploring new aspects of the course content.

Regarding feedback, there are also clear differences among the tools. The impact of CRS on feedback was rated highest. That shows that students see CRS as a useful tool to monitor their own learning, to identify their knowledge gaps and to see what they need to focus on further. Next to the CRS also the perceived impact of Lecture Recordings was rated high. A reason for that could be that students have the possibility to clarify misunderstandings and to monitor what they already know or not know by listening to lectures again. The Question Tool had a significantly lower perceived impact on feedback. This is rather unexpected. It was assumed that the Question Tool enhances monitoring of own learning progress and comparing own performance with other students. In addition, some researcher also investigated that a Question Tool promotes feedback (So, 2016; Montgomery, 2019).

Study 2

Method

Procedure and Sample

Two focus groups were conducted to collect qualitative data. The interviews took place at the end of the semester after the 12th lecture of the course "General Psychology". Students who took part in that course and had used the tools during the semester were asked to participate in the focus groups. Eleven students participated voluntarily. They did not receive any incentives or grades for taking part but had the opportunity to support shaping the future use of the tools. The first focus group consisted of four participants ($N_{female} = 4$) and the second of seven participants ($N_{male} = 2$ / $N_{female} = 7$). The focus groups lasted around 50 minutes and were audio recorded.

Measures

The researcher of this study was moderator and analyst of the focus groups and had studied the subject of digital tools in education for several months to develop a comprehensive understanding of the subject. The comprehensive understanding helped in creating the focus group guidelines and in identifying relevant themes and statements during data collection. The researcher has also extensive knowledge in conducting qualitative research due to prior studies and projects.

The purpose of the qualitative study was to get in-depth information on how students perceived the tools, the tools' impact on active learning, repetition and feedback and on how the tools and their implementation can be further improved and developed. For that purpose, focus groups were designed in line with the focus group literature (Barbour, 2014; Masadeh, 2012; Vaughn et al., 1996). Focus groups deliver several positive aspects. Participants are in a relaxed group-setting situation, discussing with their peers a topic that affects them all. Therefore, they

are more open and it is easier for them to express their opinions and perceptions (Kamberelis & Dimitriadis, 2013). By discussing a topic with other participants, the participants think more in detail about the subject and form more sharp ideas and convictions than in a single interview (Cyr, 2016). The focus group guideline consisted of broad themes and open questions so that the moderator did not have to interact a lot with the participants but rather listened and gave space for the group discussions. Discussion in a focus group usually begins first with a warm-up and a broad theme and then goes more into depth (Masadeh, 2012; Vaughn et al., 1996). According to that, the first part of the focus group consisted of an introduction and warm-up with some information regarding the study and the agenda of the focus group (3 min). The second part consisted of questions that generally asked students how they perceived the implementation of the tools and what they liked or disliked about the tools (15 min). This rather easy question aims to motivate participants to start talking and to get in the discussion mode (Vaughn et al., 1996). In the third phase, students are encouraged to think more in-depth and discuss to which extent tools had an impact on active learning, repetition and feedback (15 min). During the fourth part, students were asked to think about how tools and their implementation can be further improved and developed (15 min). In the last phase, the focus group ends with a wrap-up and a closing statement (2 min).

Data Analysis. Recordings of the focus groups were transcribed and analyzed with MaxQDA. The analysis follows Knodel's (1993) practical approach for designing and analyzing focus group studies. Knodel (1993) assumed that an analysis of focus group data consists of a mechanical and an interpretive part. The mechanical part includes organizing the data into segments and the interpretive part includes organizing the textual data into segments by coding the data. He calls the process of coding "Code Mapping". The purpose of Code Mapping is to

create a final Code System that includes all codes identified by the analysis (Fig. 3). The process includes four steps:

Step 1 *Develop an Initial Set of Codes Corresponding to Each Item in the Focus Group Discussion Guidelines.* According to the research questions and the three broad themes in the focus group guidelines, three codes were created: General impression of the tools, tools' impact on active learning, repetition and feedback and ideas for further development.

Step 2 *Create Additional Codes for Topics That Arise and Are of Special Interest.* Based on the text material further codes were created inductively, which were essential for answering the research questions and receiving a comprehensive understanding.

Step 3 *Develop Nonsubstantive Codes That Will Be of Particular Help in the Analysis and Write-Up Phases.* During the third phase, further codes are created which are particularly helpful for analyzing the material, for example to code leading statements or codes that indicate that the statements were made as jokes. In this analysis, it was not necessary to develop further nonsubstantive codes.

Step 4 *Develop Subsequent Detailed Codes to Use for Analyses of Specific Topics*. After the initial code mapping, some topics were analyzed again in detail. Based on this analysis some of the subcodes referring to the tools were differentiated in positive and negative aspects.

Objectivity and Reliability

Qualitative research analysis often lacks to an extent objectivity because analysis and interpretation depend to a certain degree on the analysist (Rabiee, 2004). To increase objectivity

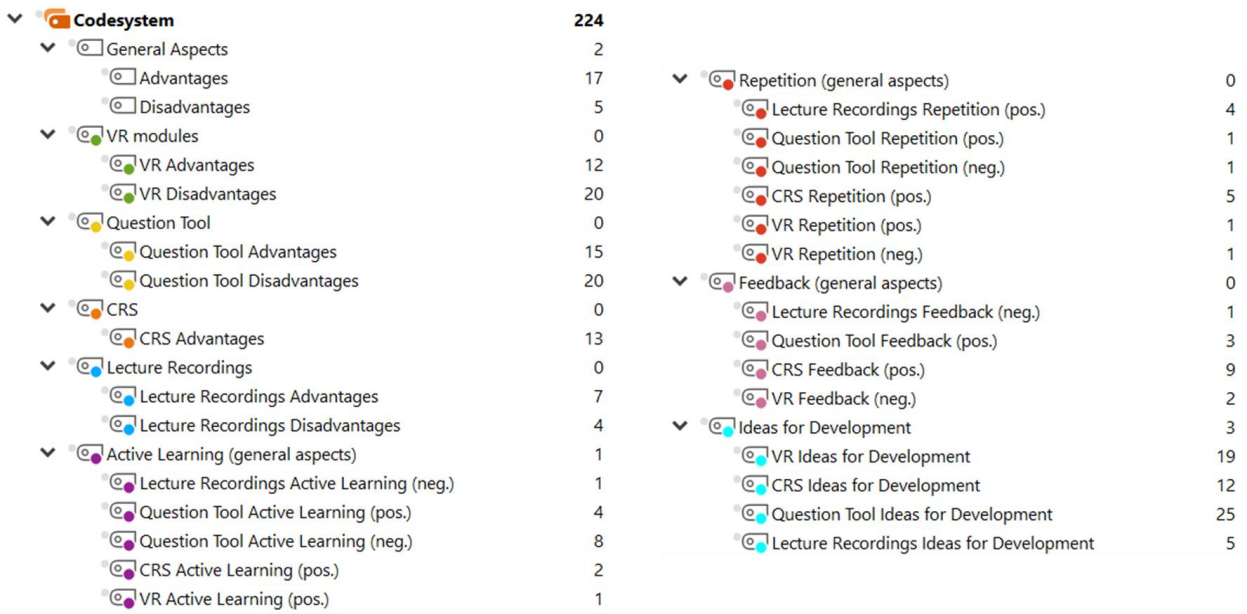
in this study, procedure of data analysis is clearly documented so that other researcher have the possibility to understand and verify findings.

Reliability of the data can be assessed by comparing statements within and across focus group sessions (Knodel, 1993). In this study, statements and codes of both focus groups were placed side by side and analyzed. Both groups answered similarly to the questions and identified same key aspects regarding the tools, their impact on active learning, repetition and feedback and their ideas for future development. These results indicate reliability for the study.

Moreover, the accuracy of the interpretive analysis is enhanced, because the analyst was also moderator in the focus groups and consequently directly involved in the process of data collection. This brings analyst and subject of the study closer together and makes the interpretation more accurate (Knodel, 1993).

Figure 3

Codesystem



Results and Discussion

General impression of the tools. The most discussed tools during the focus groups were the Question Tool (35 statements) and the VR modules (22 statements). Participants described many positive but also negative aspects of these two tools. Regarding the Question Tool, they liked the tool itself because they had the opportunity to ask questions throughout the entire lecture and it facilitated participating for rather shy students. They also thought that some of the questions were helpful for understanding the lectures' contents and getting more in-depth knowledge. On the other side, they criticized that some of the questions asked by the students were not related to the lectures' contents and therefore not interesting for all students. They also expressed that the time spent on answering the questions during the lecture was too long ("It takes so much time. Sometimes we only manage to go through 30 slides because we discuss things from the question tool for so long").

Regarding the VR modules, students enjoyed getting to know a new technology ("I also came into contact with things that I have not known before. For example VR, I have never tried that before. Of course it's super cool to try something new."). They also liked the tool because it brought fun and variety to the lecture. What they rather disliked is that the implementation of the tool including an explanation of how it works and getting it started on all students' smartphones took a lot of time. Moreover, they said that it was fun using the tool but that it did not have an effect on their learning ("In addition, it takes a lot of time until everyone is ready, has the right browser and started the module on his smartphone. For me, the time spent and what you learn at the end of it are not in proportion") . Students said that they would have understood the topics also without the VR modules. There were also some technical issues because the VR modules

did not work properly on all smartphones and some participants criticized that the VR environment was rather artificial and did not feel like the real world.

Participants also discussed the CRS (13 statements) but in contrast to the other tools, they only mentioned positive aspects about the tool ("I liked the CRS most. I was always looking forward using it because it was fun"). They said it was a great way to repeat lectures' contents and a good preparation for the exam. The least discussed were the Lecture Recordings (11 statements). In general, students were content with this tool. It offered them the possibility to repeat content so that they were not under pressure while taking notes in the lecture and to miss a class without lacking the information of the lecture.

Tools' impact on active learning, repetition and feedback. In regards to active learning students mentioned especially the Question Tool both in a positive (4 statements) and negative way (8 statements). It made them think more critically about the lectures' content to find out what they have not understood so far and how to phrase it in a question. Doing that made them more focused and engaged during the lecture. On the other side, some of the questions asked by students were irrelevant to the others and sometimes time spent on answering the questions was quite long. Because of that, participants reported that they lost attention and did not follow the lecture anymore ("I noticed for myself that I lost attention because the questions were not relevant for me. Or because sometimes stupid stuff was asked."). Regarding the other tools students were not especially aware of their impact on active learning so there were only a few mentions.

Regarding repetition, students mentioned mainly CRS (5 statements) and Lecture Recordings (4 statements) in a positive way. There were hardly any mentions for the Question Tool and VR. In terms of CRS students said that multiple choice questions helped to repeat and

better memorize lectures' contents. They also described the Lecture Recordings as a great way to repeat lectures. If students did not understand something during the lesson, they can always repeat contents with the Lecture Recordings.

Finally regarding feedback participants' focus was the positive impact of the CRS (9 statements). Students liked that the CRS provided a direct feedback and that they saw immediately if they understood the topics correctly or not. The questions gave them hints on what they still need to focus on ("You get direct feedback on whether you have understood something from the lecture or not. You also know in which areas you might have to focus on or whether you still have questions about the important topics. I think that's really good"). Participants also mentioned that the Question Tool provided feedback (3 statements). The questions asked in the tool helped them to monitor their understanding ("For some questions I noticed that I could answer them without any problems or for others I noticed that I should look at the topic again") and to compare themselves to other students

Ideas for further development. During the last part of the focus groups, participants were asked how tools should be further improved and developed to increase their impact on effective learning. In general participants liked the tools and their implementation in the course. They wished that the implementation of tools would be expanded to other courses as they see many benefits in them. However, some ideas for improvement were mentioned especially for the Question Tool (25 statements) and the VR modules (19 statements). Regarding the Question Tool, one of the main concerns was the amount of questions. Participants preferred a reduction of questions to only those who are relevant to all students and fit to the course material. Participants suggested that questions in the Question Tool are filtered and summarized by the lecturer so that not all questions are answered. This would reduce time for answering questions

and only most relevant questions would be answered. Moreover, they suggested the providing of clear guidelines for students what kind of questions are appropriate to ask ("It would be good if there were clear guidelines or at the beginning of the semester an introduction so that students know, which questions should be asked and which not"). Another idea was the introduction of a voting system. With the voting system students could vote questions of other students, for example with a thumbs-up button and lecturers could answer only most voted questions. Regarding the VR modules, participants proposed the development of other modules with a higher learning effect ("Maybe there are more complex topics where VR really helps to understand them"). For the VR modules they did at home, they would also appreciate a direct feedback on how they performed. In terms of the CRS, participants mentioned that there could be more than 3 multiple choice questions and that the tool could be used more often during the lecture.

Overall Discussion

This paper evaluated the implementation of four digital tools in a large lecture class and investigated how students perceived the tools and their impact on active learning, repetition and feedback. For this purpose, both quantitative and qualitative data were collected. During the following part, results from both data collections are integrated using a side-by-side approach to answer the research questions and identify similarities and differences.

The first research question focused on how students perceived the tools and their implementation in the lecture. Data collected during focus groups revealed that students enjoyed using the tools. They brought variety to the lecture and some of the tools helped them to learn the contents of the lectures. However, they perceived differences in the effectiveness of the tools.

Results of the quantitative study indicate that students rated the impact of a tool on active learning, repetition and feedback in a rather similar way. For example, if the impact of a tool on active learning was rated highly, the impact on repetition of this tool was rated similarly high. Reasons for that could be that the constructs are not selective and consequently students responded on items in a similar way. Confirmatory Factor Analysis also revealed that constructs correlate with each other and load on each other. Another reason could be that students see tools as either effective or not effective without differentiating if the tools have a more or less impact on the different constructs. Regarding the single tools, the Lecture Recordings received high rates for their impact on repetition and feedback in the quantitative study. Students emphasized also in the qualitative study that it is a great tool to repeat the contents of the lecture and to clarify what they misunderstood during the lecture. Previous research studies have also reported that students were enthusiastic about using lecture recording (Copley, 2007) and placed great value on them for more in-depth understanding, clarification or exam preparation (Morris et al., 2019). The Question Tool had a rather low impact compared to Lecture Recordings and CRS. Ratings were almost similar for active learning, repetition and feedback. The focus group participants reported that they liked using the tool in general and the possibilities it offered but there were some aspects of implementation that need improvement. The impact of the CRS on active learning, feedback and repetition was rated highest. Data from focus groups support this impression. Participants enjoyed using the tool because it was fun and appropriate in terms of time and effort. It also helped them to learn contents of the lecture and to prepare for the exam. These results are in line with the current literature. Most studies, investigating the effects of CRS in a classroom, identified positive aspects like an increase in attention (López-Quintero et al., 2016), in engagement (Wood & Shirazi, 2020), in motivation (Licorish et al., 2018), in

interactivity (Heaslip et al., 2014) and in academic performance (Ma et al., 2018). It was also shown that it provides instant feedback (Ismaile & Alhosban, 2018; López-Quintero et al., 2016) and is a suitable tool for student retention (Collier & Kawash, 2017). In contrast to that, students rated impact of VR modules on all three constructs rather low. Focus group participants confirmed that VR modules were less useful to them. They enjoyed exploring the new technology but it did not help them to learn lecture's contents. They also criticized that the VR environment was rather artificial and did not feel like the real-world. Because of that, it can be assumed that immersion, which is one of the most important aspects for effective implementation of VR in the classroom (Chavez & Bayona, 2018), was rather low and that for this reason ratings for VR were also rather low.

The second research question aimed to investigate the tools' impacts on active learning, repetition and feedback and to what extent there are differences between tools. Regarding active learning, all of the four tools had a similar and rather low influence. Focus group participants mentioned that they did not feel more activated and focused during the lecture. A reason for this result could be that integrating digital tools in a traditional lecture class is not sufficient to create an active learning environment. Researchers have shown that collaboration between students and group work are an important factor to enhance active learning (Fidalgo-Blanco et al., 2019). The digital tools presented in this study, however, are more likely to be used alone. To promote active learning, implementation of tools needs to be changed or other activities need to be integrated into the lecture. Among all four tools, the impact of the CRS on active learning was rated highest. This supports the findings of other researchers who discovered that using CRS increases participation and engagement in class (Heaslip et al., 2014; Stanojević & Ranđelović, 2018). On the other side, the impact of VR was rated lowest which is rather surprising because

VR is an active tool, which promotes learning by doing (Radianti et al., 2020). It also contradicts Fabris et al. (2019) who concluded from his meta-analysis that VR has the potential to act as an active learning tool as it encourages active participation and self-directed learning. A reason for the low perceived impact could be the implementation and design of the VR modules. Radianti et al. (2020) concluded from their meta-analysis that realistic surroundings and basic interaction design elements are essential for VR modules. Regarding both aspects, further development and improvement of the VR modules used in this study are necessary. For repetition, the quantitative data revealed clearer differences between the tools. Students rated the impact of CRS and Lecture Recordings highest. During focus groups, participants said that these two tools offer students the opportunity to improve understanding and memorizing of the contents by repeating them. Other studies have similar findings for the positive effects of CRS on repetition (Combes, 2019; Wang, 2015; Collier & Kawash, 2017) and the positive effects of Lecture Recordings on repetition (Ebbert & Dutke, 2020; Morris et al., 2019). The impact of the Question Tool and VR modules was rated rather low and during focus groups, participants barely mentioned them while discussing repetition. This result is not surprising because both tools are more about exploring new aspects of the lecture material than repeating what they already know. Regarding feedback, again students rated the impact of CRS and Lecture Recordings highest. From both quantitative and qualitative results, it can be concluded that CRS helped students to monitor their own learning, to see what they have already understood or not and on what they need to focus on further. The fact that CRS increases instant feedback for students is supported by several other studies (López-Quintero et al., 2016; Wood & Shirazi, 2020; Ludvigsen et al., 2015; Ismaile & Alhosban, 2018). Results for Lecture Recordings are rather surprising. During focus groups, participants barely discussed the Lecture Recordings' impact on feedback. Only one participant

said that Lecture Recordings do not provide direct feedback, which is contradictory to the quantitative results. One reason could be that by listening to the lecture again students receive some feedback by realizing, which parts they have already understood and on which they need to focus on more. The Question Tool has a rather low impact on feedback according to the quantitative data. In comparison, focus group participants mentioned that the Question Tool had a positive influence on feedback. It allowed them to monitor they own learning process, see what questions they wer able to answer themselves or what they still need to focus on. They also had the opportunity to benchmark their knowledge with other students. The positive impact of a Question Tool on feedback was also investigated by other researchers (So, 2016; Montgomery, 2019). A reason for the contradictory results could be that students perceived some negative aspects regarding the implementation of the Question Tool (too many irrelevant questions, too much time spent on answering questions) and because of that they rated its impact on feedback rather low.

The third research question asks how tools and their implementation can be further developed. Results from the focus groups revealed that there is especially potential for the Question Tool and VR modules. Students liked the Question Tool itself and the opportunities it delivered to them but also mentioned the need to change the integration of the tool in the lecture. The amount of questions needs to be limited. Participants suggested guidelines for students that clarify which kind of questions are allowed to ask or integration of a voting system. Regarding VR modules one of the main critics was that modules were not relevant for learning. Students saw no benefit compared to the traditional lecture. The question arises, for which kind of content VR is useful. Further investigations are necessary to determine whether the effectiveness of VR modules is limited to a certain type of topics or subjects.

Limitations and Further Research

It is important to recognize several limitations of the present study and to derive ideas and indications for future research. First, the quantitative data revealed a lack of validity. Fit indices were not optimal so that the hypothesized model cannot be accepted without further research. One reason for the missing fit between model and actual data could be that the three factors active learning, repetition and feedback are not selective. They correlate with each other and factors load on each other. Further research is necessary to investigate the structure and similarities between the three factors.

Second, the study explored tools and their impacts on active learning, repetition and feedback by using subjective perceptions and self-reported data. These data are important and provide essential information on how students experience the tools and to what extent improvement and development are needed. However, to a certain extent there is a lack of objectivity. Future research needs to focus on more objective methods to evaluate tools like observations of students' participation or retention tests to test the knowledge learned with the tools. Moreover, future research should use an experimental design to identify differences in active learning, repetition and feedback between groups.

Third, this study only used data from a psychology course and from one way of integrating tools. Thus, data are only generalizable to a certain degree. For further research, tools need to be integrated into other courses with other ways of implementation to examine if this makes a difference in their impact on active learning, repetition and feedback. Results may differ a lot when integrated for example in a science class. Along with this, future research needs to examine which knowledge and contents can be best learned with each tool.

Practical Implications

With the above limitations in mind, findings of the study offer a number of implications for educators, lecturers and universities. Traditional large lecture classes often fail in providing effective learning for students (Yang et al., 2018). Implementation of digital tools in these classes has the potential to enhance active learning, repetition and feedback and to promote effective learning. Digital tools are cost-effective and easy to apply. They deliver an easy way to add variety to the class and make it more exciting for students. The four digital tools evaluated in this study also offer the possibility to address students more on an individual level and to integrate all students in the lecture. When implementing tools lecturers need to keep in mind that setting and way of implementation are important factors. Tools should not take too much time from the lecture. They should rather be used asa short and fun interruption to activate students and to keep the attention level high. Moreover, contents presented with the tools should be very close to what the lecture is about and should not go far beyond the material. This is important for students to receive feedback on their current performance and to repeat contents effectively. Another aspect is that lecturers need to moderate tools. For example Question Tools can be moderated by using a voting system and responding only to the most voted questions. CRS and VR modules should incorporate short, instant feedback on how students performed. Moreover, results of the study indicate that if lecturers want to enhance particularly repetition or feedback in their class, CRS is the most suitable tool among the four evaluated tools followed by the Lecture Recordings. The Question Tool and VR modules have a rather low impact on both repetition and feedback if they are implemented the same way as in this study. Lecturers need to consider the findings of this study regarding further ideas for improvement and development when implementing Question Tool or VR modules.

Conclusion

The four evaluated digital tools Lecture Recordings, Question Tool, CRS and VR modules differ in how students perceive them and in their impacts on active learning, repetition and feedback. It can be concluded that next to the tool itself also the way of how it is implemented and used during the lecture plays an important factor. In general, using digital tools brings variety to the lecture and offers all students the possibility to participate in the lecture. In this study, students perceived CRS as most valuable for enhancing active learning, repetition and feedback followed by the Lecture Recordings. These tools are suitable for supporting traditional large lecture classes and enhancing effective learning. Question Tool and VR were perceived as less valuable. Based on the ideas for future development these two tools can be revised and improved. The findings of this study can be relevant for both future research and practical interventions aiming at investigating aspects of digital tools in a large lecture class and implementation of the four evaluated tools.

References

Abdous, M., Facer, B. R., & Yen, C.-J. (2012). Academic effectiveness of podcasting: A comparative study of integrated versus supplemental use of podcasting in second language classes. *Computers & Education*, *58*(1), 43–52. https://doi.org/10.1016/j.compedu.2011.08.021

Alfalah, S., Falah, J., Alfalah, T., Elfalah, M., & Falah, O. (2017). Perceptions toward adopting virtual reality as a learning aid in information technology. *World Academy of Science, Engineering and Technology, International Journal of Computer, Electrical, Automation, Control and Information Engineering*, *11*(4), 392-396. https://doi.org/10.1007/s10639-018-9734-2

American Educational Research Association, American Psychological Association & National Council on Measurement in Education. (2014). *Standards for educational and psychological testing*. American Educational Research Association.

Andergassen, M., Mödritscher, F., & Neumann, G. (2014). Practice and repetition during exam preparation in blended learning courses: Correlations with learning results. *Journal of Learning Analytics*, *1*(1), 48-74.

Barbour, R. S. (2014). Analysing focus groups. *The SAGE handbook of qualitative data analysis*, 313-327.

Bilyalova, A. A., Salimova, D. A., & Zelenina, T. I. (2019, May). Digital transformation in education. In *International Conference on Integrated Science* (pp. 265-276). Springer, Cham.

Bloom, B., Engelhart, M., Furst, E., Hill, W., & Krathwohl, D. (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain.* David McKay

Bonwell, C. C., & Eison, J. A. (1991). *Active learning: Creating excitement in the classroom* (ASHE-ERIC Higher Education Report No. 1). Washington, DC: The George Washington University, School of Education and Human Development.

Bos, N., Groeneveld, C., Bruggen, J. van, & Brand-Gruwel, S. (2016). The use of recorded lectures in education and the impact on lecture attendance and exam performance. *British Journal of Educational Technology*, *47*(5), 906–917. https://doi.org/10.1111/bjet.12300

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn* (Vol. 11). National academy press.

Broadbent, J., & Poon, W. L. (2015). Self-regulated learning strategies & academic achievement in online higher education learning environments: A systematic review. *The Internet and Higher Education*, *27*, 1-13. https://doi.org/10.1016/j.iheduc.2015.04.007

Brown, T. A. (2015). *Confirmatory factor analysis for applied research*. Guilford publications.

Castillo-Manzano, J. I., Castro-Nuño, M., López-Valpuesta, L., Sanz-Díaz, M. T., & Yñiguez, R. (2016). Measuring the effect of ARS on academic performance: A global meta-analysis. *Computers & Education*, *96*, 109–121. https://doi.org/10.1016/j.compedu.2016.02.007

Cepeda, N. J., Vul, E., Rohrer, D., Wixted, J. T., & Pashler, H. (2008). Spacing Effects in Learning: A Temporal Ridgeline of Optimal Retention. *Psychological Science*, *19*(11), 1095–1102. https://doi.org/10.1111/j.1467-9280.2008.02209.x

Chalil Madathil, K., & Greenstein, J. S. (2017). An investigation of the efficacy of collaborative virtual reality systems for moderated remote usability testing. *Applied Ergonomics, 65*, 501–514. https://doi.org/10.1016/j.apergo.2017.02.011

Chavez, B., & Bayona, S. (2018). Virtual reality in the learning process. In *World Conference on Information Systems and Technologies* (pp. 1345-1356). Springer, Cham.

Chickering, A. W., & Gamson, Z. F. (1987). Seven principles for good practice in undergraduate education. *AAHE bulletin*, *3*, 7.

Chien, Y. T., Chang, Y. H., & Chang, C. Y. (2016). Do we click in the right way? A meta-analytic review of clicker-integrated instruction. *Educational Research Review*, *17*, 1-18. https://doi.org/10.1016/j.edurev.2015.10.003

Clark, V. L. P., & Ivankova, N. V. (2015). *Mixed methods research: A guide to the field* (Vol. 3). Sage publications.

Coca, D. M., & Sliško, J. (2017). Software Socrative and smartphones as tools for implementation of basic processes of active physics learning in classroom: An initial feasibility study with prospective teachers. *European Journal of Physics Education*, *4*(2), 17-24

Collier, R., & Kawash, J. (2017). Improving Student Content Retention using a Classroom Response System: *Proceedings of the 9th International Conference on Computer Supported Education*, 17–24. https://doi.org/10.5220/0006218100170024

Combes, N. J. (2019). Targeting Conceptual Understanding: How to Improve Learning and Course Retention in Research Methods Courses. *Journal of Political Science Education*, *15*(3), 281–298. https://doi.org/10.1080/15512169.2018.1462189

Copley, J. (2007). Audio and video podcasts of lectures for campus-based students: Production and evaluation of student use. *Innovations in Education and Teaching International*, *44*(4), 387–399. https://doi.org/10.1080/14703290701602805

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *psychometrika*, *16*(3), 297-334.

Cyr, J. (2016). The Pitfalls and Promise of Focus Groups as a Data Collection Method. *Sociological Methods & Research*, *45*(2), 231–259. https://doi.org/10.1177/0049124115570065

Blair, J., Czaja, R. F., & Blair, E. A. (2013). *Designing surveys: A guide to decisions and procedures*. Sage Publications.

Dahlin, B., & Watkins, D. (2000). The role of repetition in the processes of memorising and understanding: A comparison of the views of German and Chinese secondary school students in Hong Kong. *British Journal of Educational Psychology*, *70*(1), 65–84. https://doi.org/10.1348/000709900157976

Denker, K. J. (2013). Student Response Systems and Facilitating the Large Lecture Basic Communication Course: Assessing Engagement and Learning. *Communication Teacher*, *27*(1), 50–69. https://doi.org/10.1080/17404622.2012.730622

Ebbinghaus, H. (1885). *Über das gedächtnis: untersuchungen zur experimentellen psychologie*. Duncker & Humblot.

Ebbert, D., & Dutke, S. (2020). Patterns in students' usage of lecture recordings: A cluster analysis of self-report data. *Research in Learning Technology, 28*(0). https://doi.org/10.25304/rlt.v28.2258

Evans, C. (2013). Making Sense of Assessment Feedback in Higher Education. *Review of Educational Research*, *83*(1), 70–120. https://doi.org/10.3102/0034654312474350

Fabris, C. P., Rathner, J. A., Fong, A. Y., & Sevigny, C. P. (2019). Virtual Reality in Higher Education. *International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International), 27*(8).

Fidalgo-Blanco, Á., Sein-Echaluce, M. L., & García-Peñalvo, F. J. (2019). Enhancing the main characteristics of active methodologies: A case with Micro Flip Teaching and Teamwork. *International Journal of Engineering Education (IJEE), 35*(1B), 397-408

Field, A. (2017). *Discovering Statistics Using IBM SPSS Statistics*. SAGE.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Fuad, M., Deb, D., Etim, J., & Gloster, C. (2018). Mobile response system: A novel approach to interactive and hands-on activity in the classroom. *Educational Technology Research and Development*, *66*(2), 493–514. https://doi.org/10.1007/s11423-018-9570-5

Gan, C. L., & Balakrishnan, V. (2016). An Empirical Study of Factors Affecting Mobile Wireless Technology Adoption for Promoting Interactive Lectures in Higher Education. *The International Review of Research in Open and Distributed Learning*, *17*(1). https://doi.org/10.19173/irrodl.v17i1.2111

George, D., & Mallery, M. (2003). *SPSS for Windows step by step: a simple guide and reference.* Allyn, Boston.

Hair, J. F., Anderson, R. E., Babin, B. J., & Black, W. C. (2018). *Multivariate Data Analysis*. Cengage.

Han, S., Capraro, R., & Capraro, M. M. (2015). How science, technology, engineering, and mathematics (STEM) project-based learning (PBL) affects high, middle, and low achievers differently: The impact of student factors on achievement. *International Journal of Science and Mathematics Education*, *13*(5), 1089-1113. https://doi.org/10.1007/s10763-014-9526-0

Hattie, J., & Timperley, H. (2007). The Power of Feedback. *Review of Educational Research*, *77*(1), 81–112. https://doi.org/10.3102/003465430298487

Heaslip, G., Donovan, P., & Cullen, J. G. (2014). Student response systems and learner engagement in large classes. *Active Learning in Higher Education*, *15*(1), 11–24. https://doi.org/10.1177/1469787413514648

Hunsu, N. J., Adesope, O., & Bayly, D. J. (2016). A meta-analysis of the effects of audience response systems (clicker-based technologies) on cognition and affect. *Computers & Education*, *94*, 102–119. https://doi.org/10.1016/j.compedu.2015.11.013

Ismaile, S., & Alhosban, F. (2018). Students perceptions of audience response system in classroom feedback: A qualitative study. *International Journal of Advanced and Applied Sciences*, *5*(4), 67-72.

Kamberelis, G., & Dimitriadis, G. (2013). *Focus Groups: From Structured Interviews to Collective Conversations*. Routledge.

Kay, R., MacDonald, T., & DiGiuseppe, M. (2019). A comparison of lecture-based, active, and flipped classroom teaching approaches in higher education. *Journal of Computing in Higher Education*, *31*(3), 449–471. https://doi.org/10.1007/s12528-018-9197-x

Kim, K., Sharma, P., Land, S. M., & Furlong, K. P. (2013). Effects of Active Learning on Enhancing Student Critical Thinking in an Undergraduate General Science Course. *Innovative Higher Education*, *38*(3), 223–235. https://doi.org/10.1007/s10755-012-9236-x

Knodel, J. (1993). The design and analysis of focus group studies: A practical approach. *Successful focus groups: Advancing the state of the art*, *1*, 35-50.

Lambert, C. (2012, March-April). Twilight of the Lecture. *Harvard Magazine.* http://harvardmagazine.com/2012/03/twilight-of-the-lecture.

Licorish, S. A., Owen, H. E., Daniel, B., & George, J. L. (2018). Students' perception of Kahoot!'s influence on teaching and learning. *Research and Practice in Technology Enhanced Learning*, *13*(1), 9. https://doi.org/10.1186/s41039-018-0078-8

Lin, M.-H., Chen, H.-C., & Liu, K.-S. (2017). A Study of the Effects of Digital Learning on Learning Motivation and Learning Outcome. *EURASIA Journal of Mathematics, Science and Technology Education*, *13*(7). https://doi.org/10.12973/eurasia.2017.00744a

Looi, C.-K., Seow, P., Zhang, B., So, H.-J., Chen, W., & Wong, L.-H. (2010). Leveraging mobile technology for sustainable seamless learning: A research agenda. *British Journal of Educational Technology*, *41*(2), 154–169. https://doi.org/10.1111/j.1467-8535.2008.00912.x

López-Quintero, J. L., Varo-Martínez, M., Ana, M., Laguna-Luna, & Pontes-Pedrajas, A. (2016). Opinions on "Classroom Response System" by First-year Engineering Students. *Procedia*

- *Social and Behavioral Sciences*, *228*, 183–189. https://doi.org/10.1016/j.sbspro.2016.07.027

Ludvigsen, K., Krumsvik, R., & Furnes, B. (2015). Creating formative feedback spaces in large lectures. *Computers & Education, 88*, 48-63. https://doi.org/10.1016/j.compedu.2015.04.002

Luttenberger, S., Macher, D., Maidl, V., Rominger, C., Aydin, N., & Paechter, M. (2018). Different patterns of university students' integration of lecture podcasts, learning materials, and lecture attendance in a psychology course. *Education and Information Technologies*, *23*(1), 165–178. https://doi.org/10.1007/s10639-017-9592-3

Ma, S., Steger, D. G., Doolittle, P. E., & Stewart, A. C. (2018). Improved Academic Performance and Student Perceptions of Learning Through Use of a Cell Phone-Based Personal Response System. *Journal of Food Science Education*, *17*(1), 27–32. https://doi.org/10.1111/1541-4329.12131

Maresky, H. S., Oikonomou, A., Ali, I., Ditkofsky, N., Pakkal, M., & Ballyk, B. (2019). Virtual reality and cardiac anatomy: Exploring immersive three-dimensional cardiac imaging, a pilot study in undergraduate medical anatomy education. *Clinical Anatomy*, *32*(2), 238–243. https://doi.org/10.1002/ca.23292

Masadeh, M. A. (2012). Focus group: Reviews and practices. *International Journal of Applied Science and Technology*, *2*(10).

Mayer, R. E., Stull, A., DeLeeuw, K., Almeroth, K., Bimber, B., Chun, D., Bulger, M., Campbell, J., Knight, A., & Zhang, H. (2009). Clickers in college classrooms: Fostering learning with questioning methods in large lecture classes. *Contemporary Educational Psychology*, *34*(1), 51–57. https://doi.org/10.1016/j.cedpsych.2008.04.002

Montgomery, L., Evans, G., Harrison, F., & Damian, D.E. (2019). Towards a Live Anonymous Question Queue To Address Student Apprehension. *ArXiv:1901.01061*.

Morris, N. P., Swinnerton, B., & Coop, T. (2019). Lecture recordings to support learning: A contested space between students and teachers. *Computers & Education, 140*, 103604. https://doi.org/10.1016/j.compedu.2019.103604

Morse, J. M., & Niehaus, L. (2016). *Mixed Method Design: Principles and Procedures*. Routledge.

Nordmann, E., Calder, C., Bishop, P., Irwin, A., & Comber, D. (2019). Turn up, tune in, don't drop out: The relationship between lecture attendance, use of lecture recordings, and achievement at different levels of study. *Higher Education, 77*(6), 1065–1084. https://doi.org/10.1007/s10734-018-0320-8

Nunnally, J. C. (1975). Psychometric theory—25 years ago and now. *Educational Researcher, 4*(10), 7-21

Palinko, O., Shimaya, J., Jinnai, N., Ogawa, K., Yoshikawa, Y., & Ishiguro, H. (2018). Improving Teacher-Student Communication During Lectures Using a Robot and an Online Messaging/Voting System. *2018 27th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*, 1–7. https://doi.org/10.1109/ROMAN.2018.8525691

Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of Engineering Education*, *93*(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Rabiee, F. (2004). Focus-group interview and data analysis. *Proceedings of the nutrition society, 63*(4), 655-660.

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education*, *147*, 103778. https://doi.org/10.1016/j.compedu.2019.103778

Rawson, K. A., & Dunlosky, J. (2011). Optimizing schedules of retrieval practice for durable and efficient learning: How much is enough? *Journal of Experimental Psychology: General*, *140*(3), 283–302. https://doi.org/10.1037/a0023956

Ray, A. B., & Deb, S. (2016). Smartphone Based Virtual Reality Systems in Classroom Teaching—A Study on the Effects of Learning Outcome. *2016 IEEE Eighth International Conference on Technology for Education (T4E)*, 68–71. https://doi.org/10.1109/T4E.2016.022

Riener, R., & Harders, M. (2012). *Virtual Reality in Medicine*. Springer Science & Business Media.

Sadler, D. R. (1989). Formative assessment and the design of instructional systems. *Instructional Science*, *18*(2), 119–144. https://doi.org/10.1007/BF00117714

Schneider, M., & Preckel, F. (2017). Variables associated with achievement in higher education: A systematic review of meta-analyses. *Psychological Bulletin*, *143*(6), 565–600. https://doi.org/10.1037/bul0000098

Silberman, M. (1996). *Active Learning: 101 Strategies to Teach Any Subject*. Allyn and Bacon.

So, S. (2016). Mobile instant messaging support for teaching and learning in higher education. *The Internet and Higher Education*, *31*, 32-42. https://doi.org/10.1016/j.iheduc.2016.06.001

Stanojević, L., & Ranđelović, M. (2018). The effect of web-based classroom response system on students learning outcomes: Results from programming course. *Megatrend Revija*, *15*(3), 213–232. https://doi.org/10.5937/MegRev1802213S

Thalheimer, W. (2006, February). Spacing Learning Events Over Time: What the Research Says. *Work-Learning Research.* http://www.work-learning.com/catalog/

Vaughn, S., Schumm, J. S., & Sinagub, J. M. (1996). *Focus Group Interviews in Education and Psychology*. SAGE.

Villena Taranilla, R., Cózar-Gutiérrez, R., González-Calero, J. A., & López Cirugeda, I. (2019). Strolling through a city of the Roman Empire: An analysis of the potential of virtual reality to teach history in Primary Education. *Interactive Learning Environments*, 1–11. https://doi.org/10.1080/10494820.2019.1674886

Vaughn, S., Schumm, J. S., & Sinagub, J. M. (1996). *Focus group interviews in education and psychology*. Sage.

Wang, A. I. (2015). The wear out effect of a game-based student response system. *Computers & Education*, *82*, 217-227. https://doi.org/10.1016/j.compedu.2014.11.004

Wood, R., & Shirazi, S. (2020). A systematic review of audience response systems for teaching and learning in higher education: The student experience. *Computers & Education*, *153*, 103896. https://doi.org/10.1016/j.compedu.2020.103896

Yang, N., Ghislandi, P., & Dellantonio, S. (2018). Online collaboration in a large university class supports quality teaching. *Educational Technology Research and Development*, *66*(3), 671–691. https://doi.org/10.1007/s11423-017-9564-8