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1 Introduction

At present more and more areas of our everyday lives are changed by the influence of mobile technology and online communication. This digitization provides us with new ways to integrate interactivity in higher education settings like university lectures attended by hundreds of students. To date a large part of university courses is still held in the chalk and talk teaching style[1] with very little feedback from the students. But as Heinz W. Engl, the current rector of the University of Vienna stated in an interview[2] earlier this year, the university increasingly strives to support education with digitization, while still prioritizing personal contact between researchers, students and teaching personnel. Research has shown that using gamification, which' concrete definition we will expand on in chapter 3: Background and Basics, is an effective way to increase student participation and a powerful tool to keep students' attention in education settings [16]. One way for lecturers to apply the positive effects of gamification to student learning is to incorporate digital tools like apps and web services into the teaching environment. By using digital tools it is now possible to have a bilateral communication channel between the lecturer and the students, even in situations where there are hundreds of participants in a course. The aim of this project was to contribute to making lecture halls more interactive and students more active participants in their own learning processes.

With the first use of the term "gamification" recorded in 2008, it is a relatively new trend [10]. Gamification has so far successfully been used in many areas including but not limited to healthcare, commerce, business, productivity and education [31] [11] [18]. The main goal of gamification is to improve motivation, engagement and to evoke a sense of playfulness that transforms the whole experience from work to play [40]. Because of these

[1] The course plan for the bachelor in computer sciences at the University of Vienna to date contains 7+ lectures (VO) and 14+ hybrid lectures (VU). Information found in the course directory 2018S at `https://ufind.univie.ac.at/en/vvz_sub.html?spl=5&anchor=5212016I`, Accessed: 2018-05-29

[2] `https://medienportal.univie.ac.at/uniview/uni-intern/detailansicht/artikel/rektor-engl-wir-befinden-uns-in-einer-spannenden-phase/`, Accessed: 2018-05-29

benefits there has been a growing interest in using gamification methods in education in recent years. While there have been several studies centered around exploring the potential of gamification in teaching and learning [21] [16] [11], there still seems to be a distinct lack of empirical evidence to clearly support claims about effectiveness of gamification in learning environments [31]. On the other hand, there are studies that have found that gamification has the potential to improve learning, but only if the activity is well designed and used correctly, e.g. in regards to framing the activity [31] [30].

While games in education have been considered to be effective [4], previously the tools that were used to integrate gamification in lecture halls were often dedicated hardware devices that were expensive to build and maintain [13]. Today surveys show [32] that most students own a laptop or smartphone with wifi capabilities, which opens up new, more cost efficient options for developing gamification tools for higher education in the form of apps and web services.

This thesis puts its focus on developing a prototype for the use in lecture halls that seeks to enhance the frontal teaching style. It adds a non-intrusive feedback channel in the form of a quiz that applies gamification methods and that the lecturer can use to:

- determine how well the information that was just presented has been absorbed by the students;
- enhance learning by addressing common deficits in real-time;
- increase students' attention; and
- motivate them to be interested and invested in the lecture.

To achieve this a web application was developed that can be used by the lecturer to introduce quiz questions at selected time points during the lecture and allows the students to participate in the quiz with their own smartphones or web browsers without having to install an app first.

The Lective web application was developed for use in a traditional frontal teaching setting, in a proposed lesson plan that alternates between 30min of teaching followed by a short quiz (3-4 questions) for recapitulation. This teaching format is intended to keep students focused on the lecture content and facilitate the exchange of vital information between students and lecturer, which we will expand on further in the chapter 7: Discussion and Limitations.

The structure of this thesis is as follows: Chapter 2 explores the work that has been done in the field of gamified tools for classroom settings. Chapter 3 gives an overview of the theoretical basis for this work starting with popular definitions of the term "Gamification", and proceeding with sections about student attention and active learning, motivation and short and long term memory. Chapter 7.2 compares six audience response tools that satisfy similar requirements as the Lective prototype. Chapter 5 first gives information about the method and data of an offline paper test that was performed in a course at the University of Vienna in order to gather data on the current state. Then the chapter proceeds to introduce the Lective prototype by listing its requirements, providing an overview over used programming languages and technologies, giving a step-by-step process definition, expounding the architecture and technology stack and giving a short classification of the development process. Chapter 6 describes the method and lists the results of a user acceptance test that was conducted with test users of the Lective prototype. Chapter 7 first describes the lecture format we propose for the use of Lective, and then compares the findings of Lective's acceptance test with other audience response tools, before finally debating the strengths and limitations of the Lective prototype. It also considers next steps and possible improvements. Finally in Chapter 8 there will be a summary of this project's results and conclusions.

2 Related Work

In this chapter we will take a look at related work pertaining to the use of gamified online tools in classroom settings, which share the following basic characteristics: each student has an input device (dedicated handset or own internet-capable device), which transmits their responses to multiple choice questions posed by the lecturer. A summary of the responses is displayed afterwards (either on the students own screens or on a shared computer screen that can be projected on a wall).

In this thesis the gamified online tools in classroom settings that are considered are called Audience Response System (referred to in the following as ARS), but in literature they are also known as:

- Audience Paced Feedback
- Audience Response Systems
- Classroom Communication Systems
- Classroom Response Systems
- Clickers
- Digital Voting Systems
- Electronic Polling Systems
- Electronic Voting Systems
- Group Response Systems
- Personal Response Systems
- Student Response Systems
- Voting-machines

2.1 Established Benefits and Challenges of an ARS

To start off, a literature review by Kay and LeSage from 2009 [20] examined 67 peer-reviewed papers published from 2000 to 2007 with the goal of determining the main benefits and challenges associated with the use of ARSs. The results were the following:

Main benefits:

- Improvements to the classroom environment (increases in attendance, attention levels, participation and engagement)
- Learning (interaction, discussion, contingent teaching, quality of learning, learning performance)
- Assessment (feedback, formative, normative)

Main challenges:

- Teachers need time to learn and set up the ARS technology
- It is challenging for teachers to create effective ARS questions
- It is challenging for teachers to provide adequate coverage of course material
- It is challenging for teachers to respond to instantaneous student feedback
- It is challenging for students to adjust to a new method of learning
- Students can get confused when multiple perspectives are discussed
- Students react negatively to being monitored

2.2 ARS Impact on Student Learning

In 2003 Uhari et al. [36] conducted an experiment in a pediatrics lecture at the University of Oulu, in which they used the commercial Electronic Voting System (aka Audience Response System, or ARS) "Interactive Presenter", which uses dedicated transmitters that are distributed to the students, to assess shortcomings of the used lecture format and to explore student responses to the addition of the voting element to the usual lecture practices. They found that the introduction of voting elements doubled the self-reported time students were active during a lecture and that it improved their learning. As far as student assessment towards lectures as a teaching format in general, the students felt that lectures helped them realize which parts of the syllabus content were important.

The authors also compiled the following list of guidelines for using voting in lectures:

- The questions should be clear and easy to understand.
- There should be a maximum of five alternative answers.
- More time should be allotted for discussion, since the use of voting elements encourages more students to participate in discourse.
- The ARS devices should be tested beforehand.
- An introduction and support should be provided for the lecturers who will be using the ARS.
- The students should be instructed on how to handle the devices used for voting.

In the qualitative study conducted by Ismaile and Alhosban in 2018 [17] 120 students participated in a course that made use of an ARS called Learning Catalytics, during lectures. The course consisted of 14 lectures and asked students to log onto an online platform (an ARS) to answer questions pre- and post-lecture. 49 of these 120 students volunteered to take part in focus group interviews afterwards that had the goal of exploring the students' perspective of ARS use. The study found that the students felt that using the ARS improved their learning by providing instant, anonymous feedback and encouraged them to adopt a deep learning approach. Concerning the instant feedback provided by the ARS, the students reported that *"the formative feedback highlighted areas in which they were struggling as well as providing positive feedback on areas in which they were excelling."*.

A systematic review by Nelson et al. from 2012 [27] analyzed 21 studies with the aim to examine the effect of ARS on learning outcomes in health professions education. They found that 14 of these studies reported statistically significant improvement in knowledge scores after using an ARS. The results of the study indicated that the use of an ARS may lead to improved short term and long term knowledge outcomes.

A study by Tregonning et al. from 2012 [35] also addressed the impact of ARSs on student learning outcomes. More specifically, as part of exploring effects of ARS use on long term memory, it aimed to compare short and long term knowledge gain by an ARS lecture format and by a common didactic lecture format. This was achieved by asking students in two courses at the University of Western Australia to complete multiple-choice quizzes immediately after each lecture and again 5 weeks later. The results were that the students' scores in the quizzes immediately post-lecture were significantly higher than in the compared common didactic course, but no differences were found in the scores for the quizzes that were conducted after 5 weeks. This suggests that

the students' knowledge gain is initially higher when a ARS is used. The paper states that ARSs can be *"an effective teaching tool that encourages active learning in a lecture format"*. However, it also states that *"for ongoing retention of knowledge students need to integrate knowledge with self-directed and ongoing learning"*. For this reason the authors recommend careful consideration when designing the questions for an ARS session *"to encourage problem solving and deeper ongoing retention of knowledge"*.

2.3 Recommendations on How to Use an ARS

The case study by Kortemeyer from 2016 [22] aimed to determine whether Classroom Response Systems (aka Audience Response Systems, or ARSs) were valid tools to assess student performance by gathering data from four introductory calculus-based physics courses at Michigan State University. The findings led to the recommendation that ARSs should not be used for testing purposes, but as a tool to foster learning. The main argument was that the psychometric properties of data provided by traditional examinations was superior to data gleaned from ARSs in terms of student performance evaluation. But the study also revealed that ARSs provide highly meaningful situational feedback, which allows for modifying lecture pace and topical coverage if needed.

This empirical study by Mathiasen from 2015 [26] takes a closer look at students' experiences with Digital Voting Systems (aka Audience Response Systems, or ARSs) by observing and interviewing teachers and students in bachelor physics lectures at the University of Copenhagen. Based on the results this paper makes the point that ARSs should be used as communication tools instead of only as tools for performance assessment and allocation of credits. But it also states that thought must be given to the way the ARS is used, e.g. that if the goal of encouraging students to actively participate in class communication is achieved, enough time must be allotted in the lecture plan for elaborated discussion of the subjects previously presented.

2.4 Summary

These papers have shown the main benefits and challenges of using Audience Response Systems, as well as noting that ARSs should be used as tools to facilitate communication

and active student participation, not as tools for student performance assessment and grading. These insights are used by this thesis as a foundation for the design decisions made in the development of the Lective prototype, as described in chapter 5: Implementation, and for the design of the teaching format described in chapter 7: Discussion.

3 Background and Basics

This chapter explores what the education theories are that build the foundation for improving lecture environments with a gamified interaction channel like the Lective prototype. In the following we will try to provide a short background on the theory of gamification, insight into different types of motivation and the positive effects of active learning on students' attention.

3.1 What Is Gamification?

Deterding et al. defines gamification as *"the use of game design elements in non game contexts"* [10]. While this definition is the most widely accepted one with more than 3000 citations (according to `http://scholar.google.at`) it is very broad and not specific to an educational context. It is important to point out that the pedagogical concept of Gamification does not necessarily involve the use of an actual game. In 2014 Andrzej Marczewski, the author of a blog called GAMIFIED UK, tried to use crowd sourcing to collaboratively find a definition for gamification by having readers submit their own definitions [41]. The following keywords were frequently repeated in the submitted suggestions[1]:

Just from this experiment it is already apparent that there is a strong connection between gamification, engagement and motivation. Ott and Tavella identified the enhancement of motivation and engagement to be the main driver for the adoption of gamification elements in educational environments [29]. A more specific definition of Gamification to the educational context was formulated by Kapp [18]: *"Gamification is using game-based mechanics, aesthetics and game thinking to engage people, motivate action, promote*

[1]From Marczewski's blog post on 2014-04-16: `https://www.gamified.uk/2014/04/16/defining-gamification-people-really-think/` Last visited on 2018-04-07.

Keyword	Occurred in % of all submitted definitions
engage	38%
people	28%
fun	25%
motivate	22%
play	16%
solving problems	16%
behaviour	16%
goals	16%

Table 3.1: Frequently occurring keywords in the definitions for Gamification submitted for Marczewski's crowdsourcing experiment.

learning, and solve problems." Let's take a closer look at some of the key elements of this definition:

- Engage: According to Kapp to engage means "[...] to gain a person's attention and to involve him or her in the process you have created" [18] and as such must be the first step in any learning situation.

- Motivate Action: Motivation is a primary concept in learning situations. Research into education often distinguishes between two types of motivation: Intrinsic and extrinsic motivation [8]. We will expand upon this concept in the next section (Section 3.3).

- Promote Learning: Gamification is a good fit for the field of education because the techniques that teachers have been using for years already incorporate many known gamification elements (like assigning points to activities and giving corrective feedback) [18]. So while the building blocks may already be found in education, introducing gamification techniques has the goal of building an engaging game space that both increases motivation and promotes learning.

- Solve Problems: Kapp suggests that gamification is an excellent tool to help solve problems, since cooperative elements can be used to focus more than one person on solving a particular problem, and competitive elements have the goal of driving participants to do their best to "win" by solving a problem first or best [18].

Studies have already proven gamification to be effective in education by keeping students engaged and increasing motivation [21] [16]. The literature review by Caponetto et al. has provided a broad overview of how gamification has empirically been tested for educational environments and has found that most research focuses on the introduction and

evaluation of gamification strategies at university level [6]. The review found that gamification was adopted for a wide range of subject areas including science, math,foreign languages It also found that the majority of gamification research systems were carried out entirely online and only few projects *"[...] were based on blended modalities comprising both face-to-face and e-learning sessions."* [6].

3.2 Student Attention and Active Learning

Keeping students' attention during a lecture is no easy task, especially considering that university classes usually last 90 minutes or longer and the students have often already been sitting in lecture halls all day. In a review of psychology literature, Wilson and Korn [39] disproved the popular theory that students' average attention span was ten to fifteen minutes long and came to the conclusion that "while there may be a pattern of decline in student attention during a lecture, the exact length of the average attention span wasn't determined." So even though we might not be able to accurately determine the length of the average attention span, research by Bunce et al. employed the students themselves in self-observation of their attention by providing them with clickers during a lecture and asking them to record whenever they noticed a break in their attention [5]. The results have shown that the most common length of attention lapse is one minute or less. Bunce et al. concluded that there is a pattern to these lapses: the data from the clicker-test showed the first attention lapse at only 30 seconds into the first lecture segment, during the "settling in"-period. The next consistent spike in attention lapses was found at 4.5 to 5.5 minutes, then at 7 to 9 minutes and again at 9 to 10 minutes into the lecture. This pattern of short breaks in attention got more and more frequent as the lecture progressed, until at the end lapses occurred about every 2 minutes. Another finding was that during periods of "active learning" fewer attention lapses were reported. "Active learning" is also known as[2] learning through play, technology-based learning or activity-based learning, and requires the active participation of each and every student. In the study by Bunce et al. the two active learning methods that were most frequently employed in the lecture were demonstrations and questions. The data also showed that that there were fewer attention lapses in the period immediately after the active learning activity [5], which would suggest that active learning not only helps grabbing students attention, but also keeps students more engaged during the next lecture segment.

[2] According to `https://en.wikipedia.org/wiki/Active_learning`, Accessed: 2018-06-02.

3.3 Motivation

A primary concept in learning situations is motivation. Only when we are sufficiently motivated we stick with an activity long enough to expand our capabilities. Psychology and education often distinguish between two types of motivation: Intrinsic and extrinsic motivation [8].

3.3.1 Intrinsic and Extrinsic Motivation

Typically frontal classroom lectures mostly try to get students to participate by appealing to their extrinsic motivation, which is behavior defined as doing something in order to gain a certain reward, or avoid a certain punishment, external to the activity itself - e.g. completing an assignment to get a good grade [24]. By introducing gamification elements to these situations, we hope to not only keep inciting extrinsic motivation (e.g. giving grades is fundamentally the same mechanic as awarding points for performance in a game), which keeps students engaged in a learning activity, but also to shift focus on fostering intrinsic motivation in the students, which often increases students' later interest in the subject and thus can even result in deeper understanding [2]. Intrinsically motivated behavior is defined as a person doing something for its own sake, for the enjoyment it provides, the learning it permits, or the feeling of accomplishment it evokes [24]. This is the kind of motivation we often experience when playing games, since the constant confirmation we get from reaching the next goal or beating the next high score gives us a sense of satisfaction and enjoyment that motivates us to keep playing. In this sense, gamification is a good fit for learning environments [11], since with complex information it can take more than one repetition to grasp a concept or acquire a skill. But if the person trying to learn is finding the activity of figuring it out itself rewarding, even when faced with multiple failed tries, they are more likely to stick with it until they are successful. Beswick even claims that intrinsically motivated activities may lead to a greater depth of learning and more creative output [2]. The key requirement for intrinsic motivation to grow is that the learner be interested in what they learn and in the process that is used to teach the subject [14]. This aspect, requirements for education environments that foster intrinsic motivation, is where the Self-Determination Theory comes in.

3.3.2 Self-Determination Theory

The Self-Determination Theory by Deci and Ryan [8] suggests that humans have three inherent psychological needs that must be satisfied to create an environment for optimal functioning by facilitating psychological well-being: competence, autonomy and relatedness.

- Competence means feeling that you have the ability to perform the task adequately and that you can control the outcome. According to Ryan and Deci [33] a sense of competence comes from previous success experiences and the ability to take on optimal challenges. A young child exploring its environment is a good example for our need for competence. Learning how to do new things by following your play instinct is part of human nature. When young children learn how to do new things, for example how to talk or how to walk,which by their complexity are difficult feats that are physically taxing and most of the time frustrating activities, it sometimes seems surprising that children keep trying until they master the activity. But the reason for this persistence is intrinsic motivation, as is often evident by the joy on a child's face when it is finally successful [15].

- Autonomy means feeling in charge of your own actions and having the freedom to choose how to perform a task [8]. This does not mean that an environment meant to facilitate learning must give the student total freedom in their actions. Sometimes even a limited sense of choice or an opportunity for self-direction can already enhance intrinsic motivation. Conversely, when a reward is offered as an incentive (an extrinsic reward) the feeling of autonomy decreases and intrinsic motivation recedes. Research has shown that the same applies for threats, deadlines, directives, pressured evaluations, and imposed goals [33] because they subtract from the feeling of being in control.

- Relatedness is the desire to interact with and be connected to others and to feel that others are relating authentically to you [9]. In the field of education this means that when students feel connected to their learning environment, e.g. because they are involved in a social activity, their engagement increases.

When a teacher can create an environment where these three needs are met, students are more likely to start enjoying the lesson and will start to get involved in learning

activities for intrinsic reasons. A student that is intrinsically motivated acts out of self-determination and is likely to be more interested in the subject, more involved in the activity and is likely to exhibit more creativity, which leads to enhanced performance [33].

3.4 Short Term and Long Term Memory

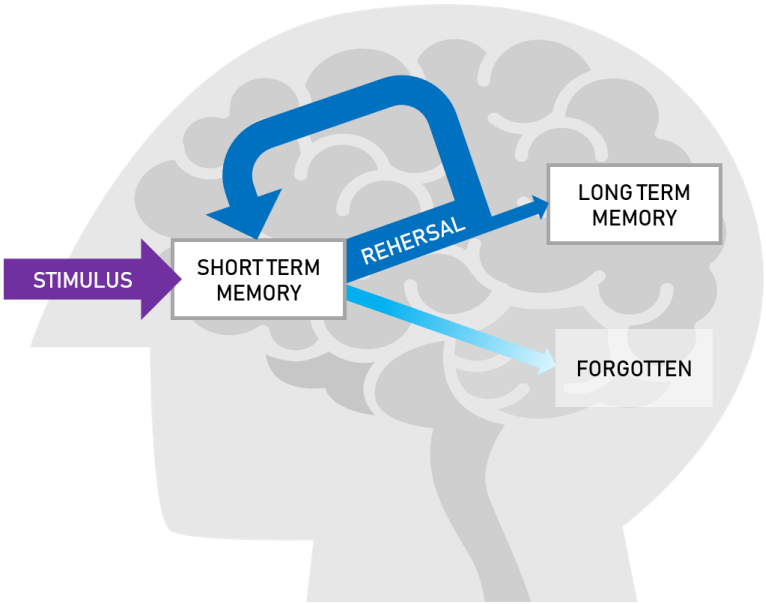


Figure 3.1: Diagram depicting Waugh and Norman's Model of Memory (1965).

Memory has long since been theorized to have two main stores: short term and long term memory. The former is used for short term storage of a limited amount of information, while the latter has a much higher capacity and is dedicated to the retention of information over the long term. Waugh and Norman claim in their Model of Memory from 1965 [38] that a stimulus first enters primary memory (short term memory) and only by rehearsing it the information can be transferred to secondary memory (long term memory), as depicted in figure 3.1. Although this idea has received considerable criticism, research shows that repetition has a positive effect on retention of information.

A more recent theory by Unsworth and Engle from 2007 [37] postulates that working memory, which is accessed when we try to recall something, relies on both short and long term memory. A limited number of information chunks, usually one to four items, may be simultaneously maintained within a person's short term memory, but anything

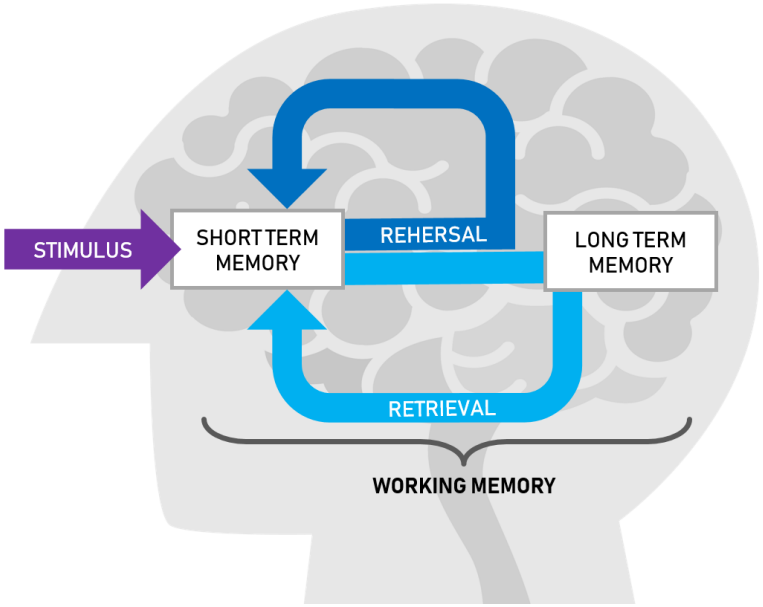


Figure 3.2: Diagram depicting Unsworth and Engle's Model of Working Memory (2007).

exceeding that would need to be retrieved from long term memory. Unsworth and Engle's theory claims that the size of the information is the main factor and even information that has been memorized only a short while ago can need to be recalled from long term memory. But there is a consensus that trying to recall something, independent of when it was memorized, mostly involves retrieving information from long term memory [28] [37]. This would mean that repetition of information, e.g. when a question is answered, can positively influence students' long term memory of the content.

4 State-of-the-Art Comparison

In the following, we will give an overview of established quiz tools intended to easily facilitate the introduction of gamification into classroom environments. These tools are audience response systems (referred to in the following as ARSs), that provide two-way communication between the audience and the host, who in our case is the lecturer. ARSs are used to interact with students during a lecture to increase engagement, attention and retention of the lecture content. The setup for an ARS usually consists of input devices for the students, a device for the lecturer or teacher to initiate and manage the interactive process, a central server and software to handle communication and feedback. With the rapid progress in smartphone development, current ARSs don't use dedicated student input devices anymore, but let the students use their own phones, tablets or laptops to interact with the system. This policy is called "Bring Your Own Device", or BYOD in short [23]. As for the lecture environments, all of the following projects are strictly web-based and rely on the following hardware infrastructure to be pre-existing in the classroom: a device for the lecturer (usually a PC or laptop), a projector or large display to share the lecturer's screen, and wireless internet for the student's devices.

The projects that were picked for the comparison all satisfy the following criteria:

- Is a web application
- Allows the creation of questions with own content
- Supports asking questions in single choice format[1]
- Reveals correct answers after question closes
- Incorporates gamification elements
- Supports participation of large number of students by their own devices

[1]Single choice is a question format where multiple answer options are given for a question, but only one answer option is correct.

Name	Website
Kahoot!	https://kahoot.com
Quizizz	https://quizizz.com
Quizalize	https://www.quizalize.com
Go Pollock	https://www.gopollock.com/en
Socrative	https://www.socrative.com
Feedbackr	https://www.feedbackr.io

All websites were last accessed on 2018-06-13.

Table 4.1: Audience Response Systems that were compared against each other based on the features defined in subsection 4.1.

4.1 Criteria for Comparison

The comparison of the selected systems had the goal of identifying the most significant features of successful ARS tools. A list of measurable criteria was compiled in two steps:

1. Compose a list of common features for audience response systems.
2. Edit the list to exclude features that could not be found in any of the six examined tools. Add new similar features that are found in at least one of the tools[2].

The final list of features was divided into the following groups:

4.1.1 General Features - Student

This group of features is concerned with basic features from the student's perspective: Which steps need to be taken before a student can participate in a quiz - Do students need to install an app? Do they need to create an account? Do they need to select a nickname for themselves? Are all the students participating in the same activity (synchronous) or are students occupied independently (asynchronous)?

[2]For example, we added the feature "column chart", after finding a column chart in the Kahoot! quiz results, because it was similar to the feature "bar chart" that was already part of the list.

4.1.2 General Features - Lecturer

Here we compare features from a lecturers perspective: Is the lecturer's screen meant to be shared with the students throughout the activity? Does the tool allow the grouping of questions, so they can be automatically asked in a consecutive order, as opposed to publishing questions individually like in a polling tool, where multiple questions can be running at the same time? Another important feature is whether quizzes can be shared, since editing an existing quiz on the desired topic instead of creating it oneself can save the lecturer a lot of time.

4.1.3 Question Types

This feature group examines which question type is the most popular among the ARSs. It will give us an overview of which question types each tool supports and how many options of question type are given by these quiz tools on average.

4.1.4 Game Elements

All of these tools employ game elements to motivate the students in their participation. This feature group examines which game elements are used and how many game elements are employed per quiz tool.

The next two feature groups explore which information is presented when, during the quiz or after the quiz is done, and to who, student or teacher?

4.1.5 Feedback While Quiz Is Running

This feature group actually examines two phases, the phase while the question is still open and the question result phase. These are the features for the question phase: Is the information how many students have selected each answer option hidden until the question is closed? Is the question displayed on the students' screens? We also wanted to know if the students can change their answer after they have chosen?

These are the features for the question result phase: How is the feedback data presented to the lecturer - in total numbers of votes? In percentage of the total number of votes? As a bar chart? Or as a column chart? Does the ARS tool display a leaderboard on the lecturer's screen after each question? Does the lecturer's screen provide the information which of the answer options was the correct one? We also examined the feedback that was presented to the student - Does the student's screen show which answer the student had selected? Does it show if that answer was correct or not? If not, does it provide the information which of the answer options was the correct one? If the student has completed this quiz before: Does the tool enable the student to compare their current performance to their previous performance? Does the tool display the student's personal score, in points, after each question? Does the tool display the student's current rank on the leaderboard on the student's screen after each question?

4.1.6 Feedback After Quiz Is Done

This feature group deals with overall quiz information presented after all the questions are done. For the lecturer's screen we wanted to know: Does the tool give the percentage of the total number of votes that were correct for each question? Does it present this data as a bar chart? Or as a column chart? Does the tool employ a leaderboard on the lecturer's screen? Does it give a detailed table of student answers for each question? Does the tool draw any conclusions from the student answer data, e.g. "Hardest Question" etc.? Does the tool offer the feature of a downloadable report of the quiz results? For the student's screen we wanted to know: Does the tool provide each student with their personal accuracy rating[3]? Does it display a personal score (in points)? Does it display a personal score (in total questions correct)? Does it display each student's personal rank on the leaderboard on their screen? Is there a list of the quizzes questions with the student's selected answers? Is there a list of the quizzes questions with the correct answers?

[3]Accuracy refers to the correctly answered questions as percentage of the total number of questions.

4.2 Tool Comparison

The result of the comparison of the tools Kahoot!, Quizizz, Quizalize, Go Pollock, Socrative and Feedbackr in terms of the previously defined features are listed in the eight tables 4.2 to 4.9. The *-indicators in the tables represent additional options.

General Features - Student

Features	ARS Tools					
	Kahoot!	Quizizz	Quizalize	Go Pollock	Socrative	Feedbackr
Installation required?	-*	-	-	-	-	-
Account required?	-	-	-*	-*	-	-
Anonymous participation?	x	x	x*	x	x	x
Shared activity? (synchronous)	x*	-	-	x	-	x

Table 4.2: Comparison result for feature group "General Features - Student".

Finding 1: No installation or sign up required.
The comparison showed that all of the tools provided their services via a website, so no installation was required to participate. The *-indicator in the table means that while no installation is required for participation in the original quiz mode, Kahoot! also offers a dedicated smartphone app, which is required for participating in quizzes that were given as homework. Creating an account was not required by any of the tools, but Quizalize and Go Pollock both offer options for voluntary sign up. Quizalize gives the lecturer the option to decide how students can participate: either without sign up, or by signing up with a dedicated Quizalize account, or with their Google account, or with their Microsoft Office 365 account. Go Pollock also offers students the option to sign in with their Google account.

Finding 2: Anonymous participation.
All of the tools supported anonymous participation for the students, either by asking them to give themselves a nickname or by automatically assigning nicknames. Kahoot! even offered lecturers the option to enable an animal-themed nickname generator for the students. Only Quizalize asked for "First and Last Name", but since there was only one text field and no verification there was nothing really stopping users from just giving a nickname.

Finding 3: There are two categories: synchronous and asynchronous activity tools.
Only three of the six tools, Kahoot!, Go Pollock and Feedbackr, were designed to be a shared classroom experience in their main mode of operation. By "shared classroom experience" we mean that the lecturer and all the participating students synchronously take part in the same phases of the quiz, e.g. all the participants answering the same question at the same time and transitioning to the next phase in unison. Quizalize, Quizizz and Socrative follow a different approach, they were designed for asynchronous activity, which by our definition encompasses two different settings:

1. The asynchronous classroom, in which the lecturer and all participating students are focused on the same quiz at the same time, but each student completes it individually, at their own pace. Many of the examined tools even offered options for scrambling question order and/or answer order to facilitate participation of individuals.

2. The asynchronous activity, where a quiz was given as "homework", often with a deadline, and students can choose freely when to submit their answers within this time frame.

Only one of the tools supports both modes of operation: Kahoot! offers the feature of giving quizzes as "homework", to be completed asynchronously with a dedicated app, even though it was primarily designed to be used as a synchronous classroom experience.

General Features - Lecturer

Features	ARS Tools					
	Kahoot!	Quizizz	Quizalize	Go Pollock	Socrative	Feedbackr
Is lecturer screen meant to be shared?	x	-	-	-	-	-
Can multiple questions be run consecutively as quiz?	x	x	x	x	x	-
Share questions/quizzes?	x	x	x	-	x	-

Table 4.3: Comparison result for feature group "General Features - Lecturer".

Finding 4: Most tools support question grouping.
Five out of six tools let the lecturer group multiple questions to a quiz, so when the quiz is started the questions are asked consecutively. This feature is a strong contrast to the modus operandi of general polling tools[4], where each question needs to be pub-

[4]Polling tools were excluded from the comparison since they did not meet the requirement of "Reveals

lished individually and stays open until polling is closed, thereby even allowing multiple questions to run at the same time. The only tool with polling-tool-like handling of the questions was Feedbackr, all the other tools employed automatic question sequencing.

Question Types

Features	ARS Tools					
	Kahoot!	Quizizz	Quizalize	Go Pollock	Socrative	Feedbackr
Single-choice?	x	x	x	x	x	x
Multiple-choice?	x	x	-	x	x	x
True/False?	-	x	x	x	x	-
Free text/open question?	-	-	-	x	x	x
Sorting?	x	-	-	x	-	-
Image?	-	x	-	x	-	-

Table 4.4: Comparison result for feature group "Question Types".

Finding 5: Most tools support questions in single- and multiple-choice format.
All of the tools provided the option of creating single-choice questions, which are defined as a question type where multiple answer options are provided but only one answer is correct. All but one of the tools also supported the creation of multiple-choice questions, which are defined as questions with multiple answer options, where more than one answer is correct. The minimum and maximum number of answers one could create per single- or multiple-choice question varied greatly. Most tools required the input of at least two answer options. Only two tools deviated from this:

- Quizalize supports the creation of questions with only one answer, by presenting students with a jumbled version of the answer that needs to be arranged in the right order to solve the question.
- Kahoot! only supports the creation of questions with exactly four answers.

In terms of the maximum number of answer options:

- Quizalize supports up to four answer options.
- Quizizz accepts five answer options.
- Go Pollock, Socrative and Feedbackr allow the creation of questions with over 100 answer options.

correct answers after question closes".

Game Elements						
Features	ARS Tools					
	Kahoot!	Quizizz	Quizalize	Go Pollock	Socrative	Feedbackr
Timer?	x	x*	x*	-	-	-
Points?	x	x*	x*	x	x	-
Leaderboard?	x	x	-	-	-	-
Rewards?	x	x	x	-	-	-

Table 4.5: Comparison result for feature group "Game Elements".

Finding 6: No Timer.
Although the standard settings of three of the six compared tools utilized a timer while a question was open, two of these tools provided options for turning off the timer, which also negated the impact faster answers had on awarded points.

Finding 7: Most tools award points, but no leaderboard.
All but one of the quiz tools gave the students points. This category includes tools that give feedback in total numbers of correct answers, e.g. "3 of 5 questions correct", but also those that compute a score based on a number of points per correct answer, possibly bonus points for faster answers and possibly bonus points for so called "Answer Streaks", meaning strings of consecutive correct answers. Feedbackr was the only tool that did not employ the point-mechanic in any way or form. Quizizz and Quizalize gave the lecturer the choice to disable the point score feature in the quizzes options. Giving scores is an effective motivational tool in games, as long as the player has a frame of reference. For example, in a competition players compare their scores with the scores of their competitors. Experience points in games can also be considered a score of sorts, with the player knowing how many points they need to gather for the next level up. In the same way as experience points, many applications that use gamification have been setting goals and tracking their user's progress in achieving them, e.g. fitness apps that track a user's daily steps would display "2465 of 10000 daily steps taken". The most common frame of reference given in the six quiz tools we examined was ranking students on a leaderboard by their scores.

Only two of the tools, Kahoot! and Quizizz, ranked students on a leaderboard. This is noteworthy, since it means that three of the five quiz tools that awarded points did not give any frame of reference to the participants, as far as we could tell.

"Rewards" is a rather abstract game element, since rewards can be given in a number of forms. To put it simple, a reward is something given in return for a service or an accomplishment[5]. In the case of these quiz tools, three tools, Kahoot!, Quizizz and Quizalize, gave out rewards, which took the form of praise, a star rating, or funny pictures called memes.

Feedback While Quiz is Running - Lecturer Screen

Features	ARS Tools					
	Kahoot!	Quizizz	Quizalize	Go Pollock	Socrative	Feedbackr
Hide student votes until question is closed?	x	-*	-	-	x*	x
Total number of votes?	x	x	-	-	-	-
Percent of votes?	-	-	-	-	-	-
Bar chart?	-	-	-	-	x	-
Column chart?	x	-	-	-	-	-
Leaderboard?	x	x	-	-	-	-
Indicator for correct answers?	x	-	-	-	-	-

Table 4.6: Comparison result for feature group "Feedback While Quiz is Running - Lecturer Screen".

Finding 8: Tools that share the screen hide votes until the question is closed.
Half of the tools waited until a question was closed to display answer distribution on the lecturer's screen, the other half updated how many participants had picked each answer option in real-time. As expected, all of the tools that immediately showed answer distribution on the lecturer's screen didn't mean for the screen to be shared with the students. Quizizz displayed a table that showed how many correct and incorrect answers were submitted per question that was updated in real-time, though this table was located on the second tab of the lecturer's user interface. Socrative did not immediately display this information, but there was a button on the lecturer's page labeled "How'd we do?" that lead to a similar table which was also updated in real-time. Feedbackr on the other hand only reveals answer distribution after a published question is closed. It displays percentages, but no total numbers of votes, and represents this information as a bar chart.

Finding 9: Most tools display the question on the student's screen.
All tools except for Kahoot! chose to display the question on the student's screen, which

[5]According to the definition of "reward" in the Merriam- Webster dictionary at `https://www.merriam-webster.com/dictionary/reward`, Accessed: 2018-06-05

Feedback While Quiz is Running - Student Screen

Features	ARS Tools					
	Kahoot!	Quizizz	Quizalize	Go Pollock	Socrative	Feedbackr
Display question?	-	x	x	x	x	x
Possible to change answer?	-	-	-	x*	x*	x
Indicator for selected answer?	-	-	x	x	-	x
Indicate if selected answer was correct?	x	x	x	x	x	x
Indicator for correct answers?	x	x	x	x	x	x
Self-comparison with previously given answers?	x	-	-	-	-	-
Display personal score (in points)?	x	x	x	x	x	-
Display personal score (in total number of correct answers)?	-	-	-	x	x	-
Display rank on leaderboard?	x	x	-	-	-	-

Table 4.7: Comparison result for feature group "Feedback While Quiz is Running - Student Screen".

is a necessity, since they do not share the lecturer's screen with the students. With only one screen, any information not displayed on the students' screens during the quiz would not be available to them.

Finding 10: Half of the tools permit students to change their answer.
Three tools, Go Pollock, Socrative and Feedbackr allowed students to change their answer as long as the question was open. Go Pollock and Socrative both provided the lecturer with the choice to disable this feature in the options.

Finding 11: After the question closes, display the correct answer and the student's given answer on the student's screen.
All six tools used the students' screens to display which answer options had been the correct ones and whether those answer options had been the ones the student had selected. Only half of the tools, Quizalize, Go Pollock and Feedbackr, also indicated which answer had been selected if it was incorrect.

Finding 12: Most tools display each student's personal score on the student's screen.
All tools except for one implemented personal scores for the students either by awarding points for correct answers, sometimes even taking time to answer into consideration, or simply by giving one point for each correctly answered question.They displayed students' new personal score on the students' screens after each question. Only Feedbackr didn't employ any kind of score.

Feedback After Quiz is Done - Lecturer Screen							
Features	ARS Tools						
	Kahoot!	Quizizz	Quizalize	Go Pollock	Socrative	Feedbackr	
Percent of correct/incorrect votes per question?	-	-	-	-	x	x	
Bar chart?	-	-	-	-	x	x	
Column chart?	-	-	-	-	-	-	
Leaderboard?	x	x	-	-	-	-	
Detailed table of student answers?	-	x	x	x	-	-	
Conclusions (e.g. "Hardest question" etc.)?	-	x	x	-	-	-	
Downloadable report?	x	x	-	x	x	-	

Table 4.8: Comparison result for feature group "Feedback While Quiz is Running - Lecturer Screen".

Finding 13: Half of the tools give the lecturer a detailed table of student answers after the quiz is done.
Quizizz, Quizalize and Go Pollock gave the lecturer a detailed table of which student answered which question correctly, incorrectly, or not at all.

Finding 14: Most tools offer the lecturer a report for download.
Kahoot!, Quizizz, Go Pollock and Socrative offered the lecturer some sort of downloadable report with data on the students' performance, but others only provided this feature for premium account users. The tables only cover features from the free versions of all six tools. Some tools, like Go Pollock, provide basic downloadable reports to users of the free version and offer more comprehensive reports to premium users.

Feedback After Quiz is Done - Student Screen							
Features	ARS Tools						
	Kahoot!	Quizizz	Quizalize	Go Pollock	Socrative	Feedbackr	
Detailed table of student's answers?	-	x	x	x	-	-	
List of questions with correct answers?	-	x	x	x	-	-	
Display personal score (in points)?	x	x	x	-	-	-	
Display personal score (in total questions correct)?	x	x	-	x	x	-	
Display personal accuracy (% correct)?	-	x	x	-	x	-	
Display personal rank on leaderboard?	x	x	-	-	-	-	

Table 4.9: Comparison result for feature group "Feedback After Quiz is Done - Student Screen".

Finding 15: Half of the tools show each student a list of the questions, their given answers, and the correct answers after the quiz is done.
Quizizz, Quizalize and Go Pollock provide a table on each student's screen, listing each question and the student's chosen answers. Furthermore, they clearly indicate whether the chosen answers were correct, and if not, provide the correct answers.

Finding 16: Most tools display a student's personal score in total number of correctly answered questions.
Kahoot!, Quizizz, Go Pollock and Socrative gave the students scores in total numbers of correct answers, e.g. "3 out of 5 correct" or "3 correct, 2 incorrect". In addition, the first two tools also gave each student a personal score in points and used this score to display each student's rank on the leaderboard on their own screen.

5 Implementation

This section provides further information on the structure and implementation of the Lective prototype. It starts by presenting the results from the offline quiz that was conducted in order to get a baseline on student comprehension in the university course the Lective prototype was developed for. Then we will be detailing the requirements for the prototype and giving an overview of the relevant technologies.

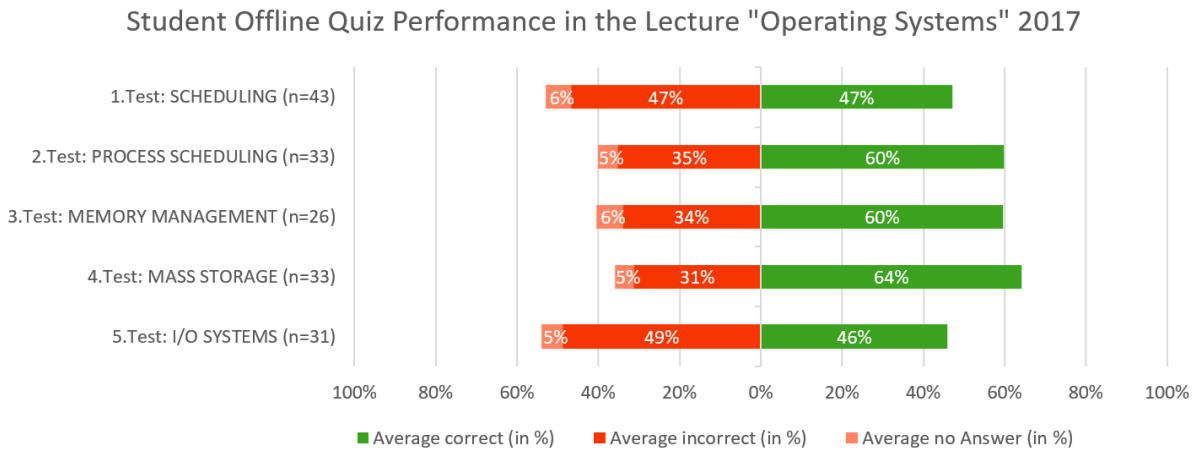
5.1 Baseline

To get a baseline of student comprehension without app support we visited five of twelve lecture units of the course "Operating Systems" at the University of Vienna in the summer semester of 2017. At the end of each lecture, we asked the students to fill out paper sheets with eight questions[1] each from the topic area they had just heard. The students were told that there would be an ungraded self-assessment test at the end of the lecture, and that the gathered data would be used to develop a quiz tool with the purpose of making lectures more interactive. A total of 166 responses were analyzed. All data was gathered anonymously. The questions for each quiz were taken from a pool of questions provided by the publisher Wiley of the book Operating System Concepts by Silberschatz et al. [34], that the lecture was loosely based on. All questions were posed in the multiple choice format with at least one correct answer option. For only the first quiz we added the free text question *"Did this test help you identify which areas of the lecture you've understood and remembered and which areas might need reviewing?"* to collect information from the students on whether the quiz was fit for purpose. The

[1] All tests consisted of eight questions, but in the fourth lecture about Mass Storage not all topics that had been planned for this unit could be covered in time. For this reason the test sheets were handed out with questions three and four crossed out, and only answers to the remaining six questions were included in the test data.

content of all quizzes can be found in the appendix at the end of this thesis.

For the evaluation it should be noted that for questions with more than one correct answer option only responses which ticked all the correct boxes were counted as correct answers. All percentages were rounded to whole numbers.



The bars represent average % of correct and incorrect answers across all students. The y-axis is labeled with the topic that was taught in each of the five lecture units and the number of students that participated on that day.

Figure 5.1: Student performance in the offline paper quiz held on five separate dates in the course "Operating Systems".

Our expectation to see the percentage of correct answers in average rise as students learned to expect a quiz at the end of each unit seemed to be proven correct at first, but the data from the last lecture unit on I/O Systems did not carry on this trend. One student even explicitly told us as part of their response to the open text question, that *"[...] Being told in advance that I was going to take an assessment [test] later on, has not boosted my studying moral."* We believe that the lecture topics of this course might vary too strongly in their complexity to be able to clearly display this kind of trend. Also, speakers often changed between lecture units and employed a variety of different speaking styles to engage the students.

We would like to examine the data by the example of the first multiple choice test on the topic of Scheduling. As shown in figure 5.1, in average the students answered 47% of the eight questions correctly, while 47% were answered incorrectly and 6% of the questions

were not answered at all. Since the percentage of not answered questions is constantly at 5-6% across all quizzes and the distribution of not answered questions does not seem to grow towards the latter questions of the quizzes, we assume that the time given for finishing the quiz was sufficient and that it was not a major factor in why these questions were not answered.

Regarding the question *"Did this test help you identify which areas of the lecture you've understood and remembered and which areas might need reviewing?"*, that was asked at the end of the first quiz, 51% of the students answered with "yes" or in another positive manner. 35% gave no answer to the question and only 14% answered negatively. Four of the six students that answered the question negatively gave reasons that are listed below, ranked by frequency:

1. *"No, I already knew that I didn't pay attention and thus have no idea about anything."* Not having paid enough attention to the lecture was mentioned by five students (12%), though the other four still responded neutrally or even positively to the quiz.

2. *"The test checked facts, not understanding."* This was mentioned by two students and the second student elaborated in German that they came to the lecture to grasp the bigger concepts and that names and formulas were something that should be studied at home.

3. *"Not really, my English is not very good. Plz German."* Only one student expressed English to be an obstacle.

5.2 Requirements

The comparison of tools in chapter 2 - Related Work led to the drafting of the following requirements for the Lective prototype:

1. Cross-platform capabilities
2. No installation required - Prioritize web service over smartphone app to eliminate obstacles like insufficient storage
3. Simple web-based user interface

4. Semi-anonymous voting (leaderboard shows self given nickname instead of e-mail addresses)
5. Single- or Multiple-choice questions
6. Require students to create accounts, to be able to create more meaningful data sets[2].

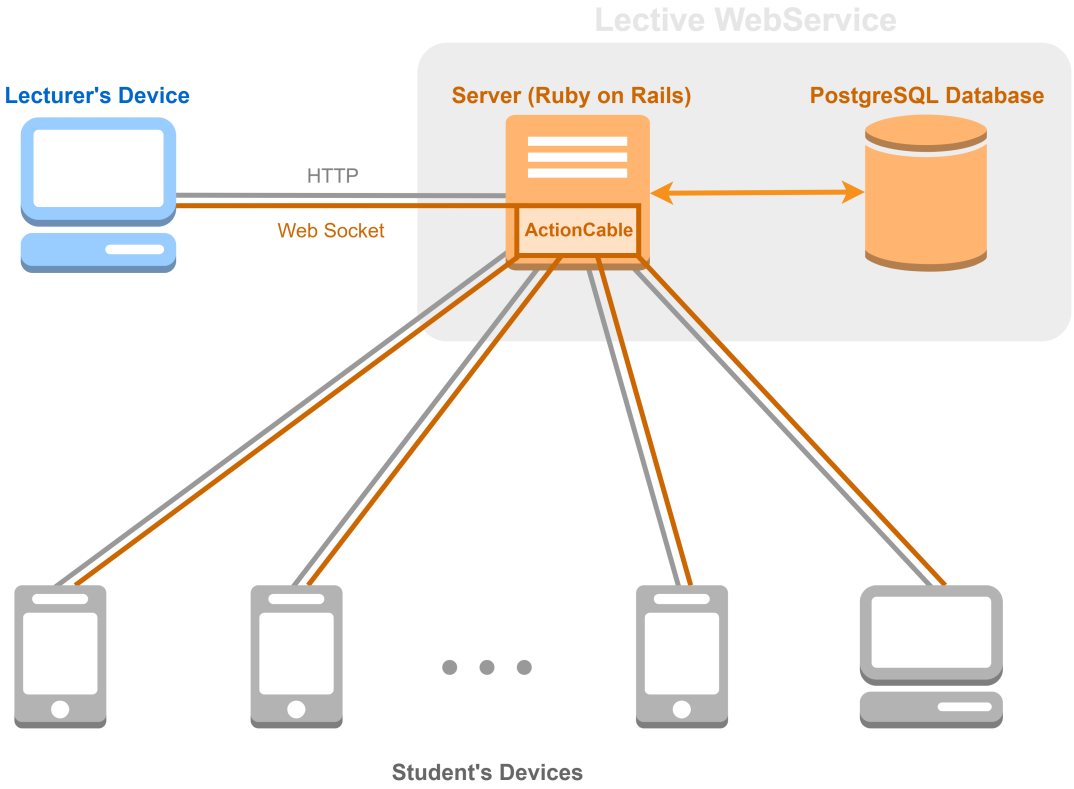


Figure 5.2: Lective web service's deployment overview.

Programming languages that were used in creating the Lective prototype:

Name	Purpose
Ruby 2.3.3	Used for most of the code since it was built on the Ruby on Rails framework.
CoffeeScript	Used by ActionCable to handle content sent over the WebSocket connection.
HTML	Used for web pages.
CSS	Used for website layout.

Table 5.1: Programming languages that were used in creating the Lective prototype.

[2]By being able to group data sets by student we have the option of motivating participants by showing long term positive trends (Pending for a future version of Lective)

5.3 Integration Overview

First we will explain the concept of the Lective prototype. Then we will have a look at the base framework this prototype was built on: Ruby on Rails, where we will briefly introduce some of its components and the libraries (called "gems") that were used to implement the planned functionality.

Technologies and code projects that were discarded during the development of the Lective prototype:

Name	Purpose	Reason for Abandonment
Electron	Framework for the development of desktop GUI applications using Node.js runtime for the backend and Chromium for the frontend.	Using Electron was abandoned once the decision had been made that students should be able to participate using their phones. The premise was that requiring students to install a dedicated app would increase the threshold for participation. For this reason it was decided to make a web application since that could be used by any phone with internet access, regardless of its operating system.
JHipster	Web application generator using Angular and the Spring Framework.	The generator was an interesting option, but the RoR framework already had an established community.
real-time Weekly blog demo project "Building a real-time quiz with PubNub"	A tutorial project that offered real-time quiz functionality.	The project was too old (RoR version) and it could not be updated, since the gems it used had changed too much. Getting the project to work would have taken too much time.
PubNub API	API for WebSocket real-time functionality	Using the PubNub API was abandoned after discovering that recent versions of RoR offered a native solution for incorporating WebSocket communication: ActionCable.

Table 5.2: Technologies and code projects that were discarded during the development of the Lective prototype.

Main technologies and code projects used in creating the Lective prototype and their specific purposes:

Name	Purpose
Ruby on Rails 5.0.2	Web-application framework (Section 5.6)
ActionCable	WebSocket interface for RoR to enable real-time functionality (Section 5.6.2)
Redis Server	In-memory data structure store, cache and message broker used by ActionCable
Devise gem 4.2.1	RoR library for user authentication (Section 5.6.1)
Bootstrap-sass gem 3.3.7	RoR library for integrating Bootstrap front-end web framework
Chartkick gem 2.2.4	RoR library for integrating charts of various APIs; the current prototype uses Google Charts (Section 5.6.3)
Google Chart API	Web service for creating graphical charts from user-supplied data
PostgreSQL	Database (Section 5.6.4)

Table 5.3: Main technologies and code projects used in creating the Lective prototype and their specific purposes.

5.4 Lective Prototype - Process Definition

The Lective prototype is a web service that was built for use in frontal lecture environments and allows lecturers to engage their students with short multiple choice quizzes. It was designed as a way to get feedback about student's retention at the end of a topic block in the lecture.

5.4.1 Quiz Preparation

The Lective web service lets lecturers create quizzes in advance. These quizzes are saved permanently to their account to be started at a later time and can be reused or edited if the lecture content changes.

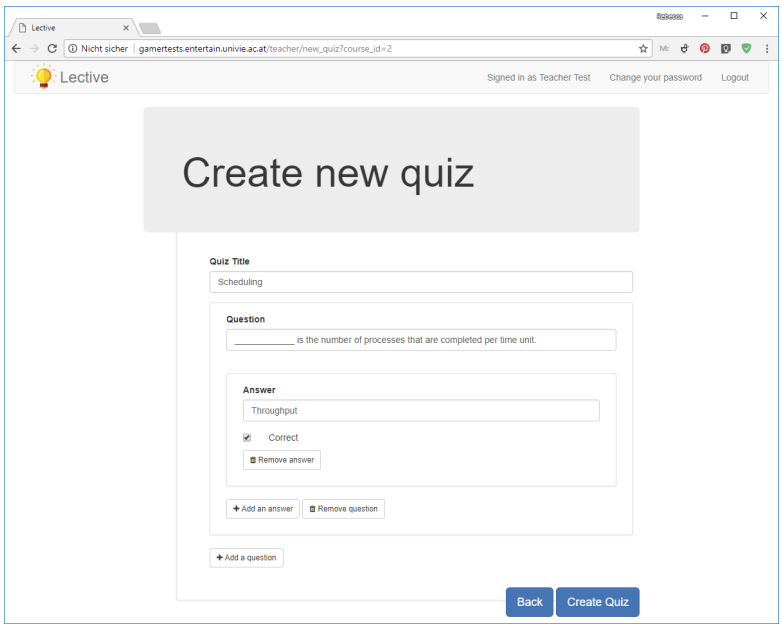


Figure 5.3: Lective Create New Quiz page.

When a lecturer wants to use one of their prepared quizzes, they log into the Lective website and select the quiz ("Start Quiz").

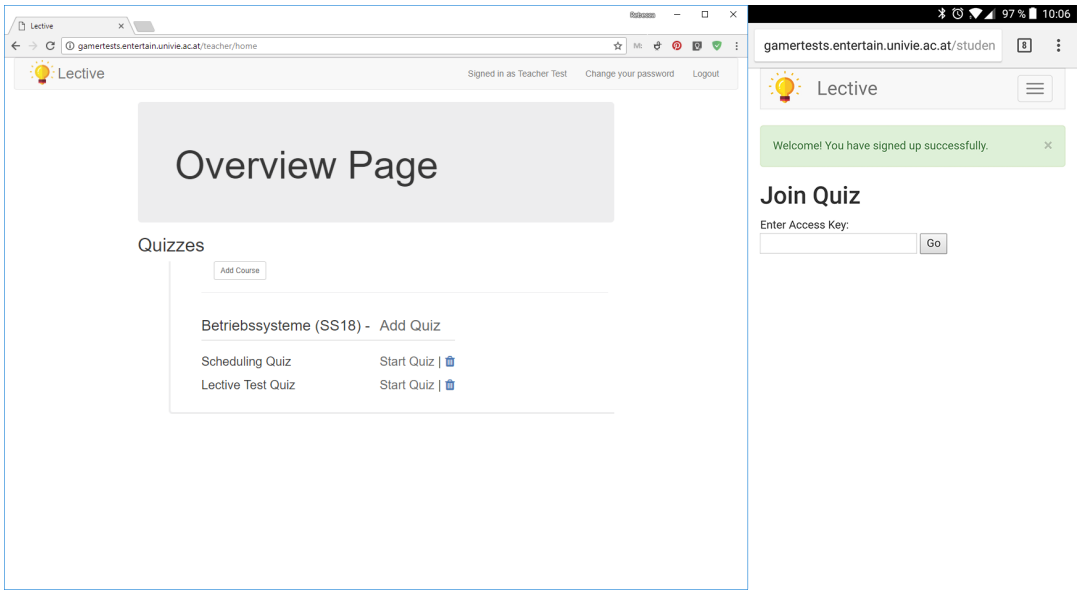


Figure 5.4: Lecturer Home page with a list of all created quizzes (left) and Student Home page with the access code field (right).

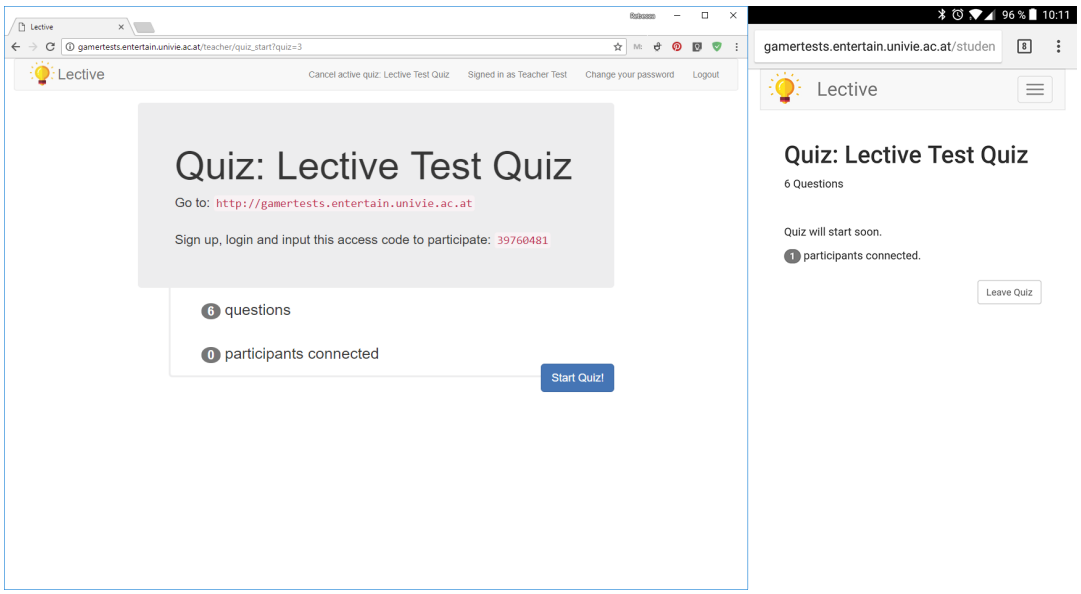


Figure 5.5: Lecturer Quiz Start page (left) and Student Quiz Start page (right). The lecturer screenshot was taken before the student joined the quiz session.

Now the screen displays the title of the quiz, the Lective URL, an access code, a counter for how many students are connected so far and a "Start Quiz" button (figure 5.5). From this point on the lecturer's screen needs to be visible to the students, e.g. by projecting it to a wall or a big screen. To connect, a student navigates to the Lective website on their smartphone or Laptop, logs in to or creates a student account and enters the access code (figure 5.4) that is displayed on the lecturer's screen. After that they will be forwarded to a waiting page until the lecturer starts the quiz (figure 5.5).

5.4.2 Starting a Quiz

Once everyone is ready the lecturer presses the "Start Quiz" button to display the first question.

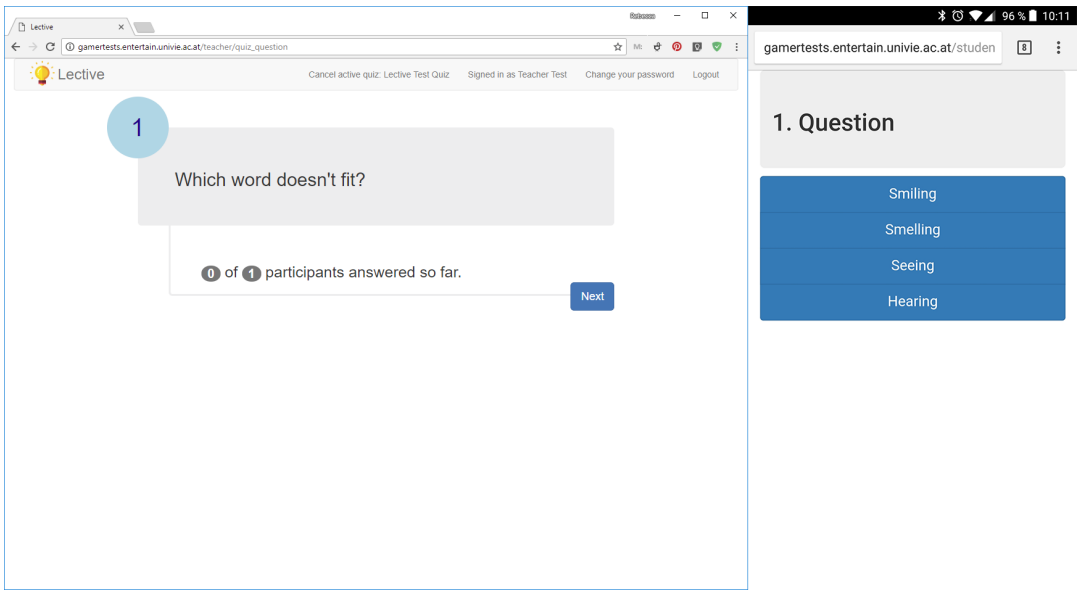


Figure 5.6: Lecturer Quiz Question page (left) and Student Quiz Question page (right).

This page also has a "Next" button, a counter that shows how many students have selected answers so far and the total number of connected students (figure 5.6). This is necessary since the number of connected students might change while the quiz is running due to disconnects. Pushing the "Start Quiz" button also automatically changes the content of the student's screens to display buttons labelled with the answer options (figure 5.6). Once a student presses one of these buttons, all buttons are locked and the selected option's background lights up. A previous version of the lecturer's question page also included a timer that was counting down, but feedback showed that most lecturers like to be in control themselves and set their own pace to be able to react to how quickly the students finish and to keep the lecture's planned time table. In the current version of Lective the lecturer decides when to transition to the next step, the presentation of the question's solution, by pressing the "Next" button. The lecturer is aided in this decision by the "students answered" counter that is updated in real-time. A common concern raised by lecturers in university environments is lecture attendance, since the students' presence often is not mandatory. To make sure that only students who are attending can participate in the quiz, we chose to not display the questions on the students' smartphones, but on the lecturer's shared screen instead. This way, while a student connecting to the Lective website from home still gets the multiple choice answers pushed to their phone, they don't know what the question was, unless the lecture is being streamed over the internet. It is our hope, that in this way Lective

can help make lectures more interactive, but also more attractive to attend in the first place.

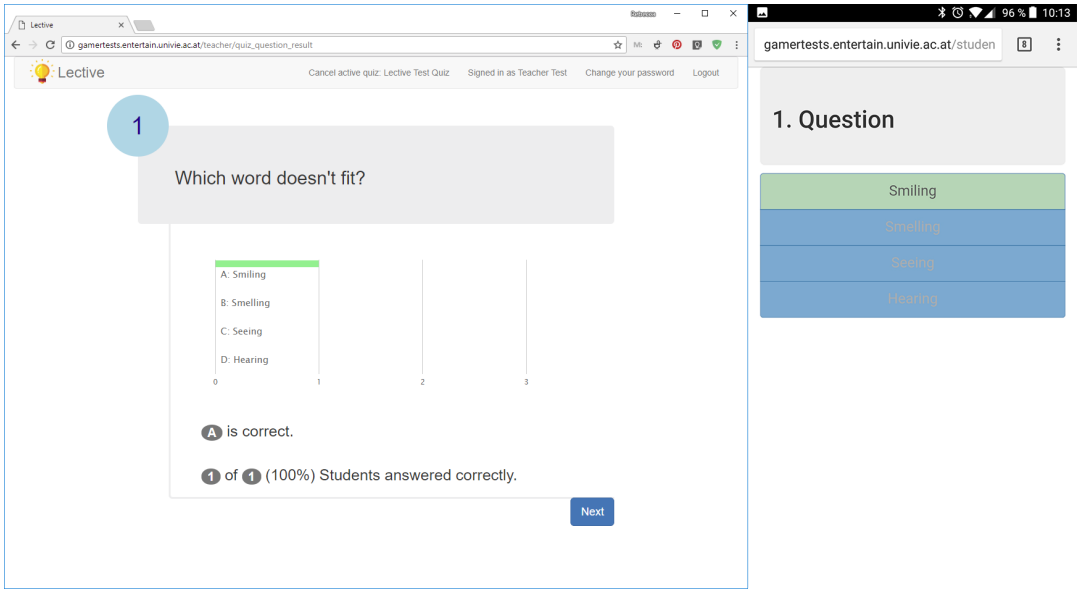


Figure 5.7: Lecturer Quiz Question Result page (left) and Student Quiz Question Result page (right).

Once the lecturer presses the "Next" button on the question page, the corresponding question results are loaded, showing the question, all four answer options and for each a corresponding bar that indicates how many students selected which answer. The color of the bar also indicates which answer was the correct one (the correct bar is green, the others are grey). The students' screen still shows the four locked answer buttons, but the selected button is now tinted either red or green, depending on whether it was the correct answer or not. Should the student not have picked any answer before the lecturer proceeded, all buttons are locked and greyed out and a message appears on the students' screen: "No answer given.". This is also reflected on the lecturer's screen with a separate grey bar.

5.4.3 Ending a Quiz

When the lecturer is done with the answer page, they can switch to the next question by pressing the "Next question" button. In this way the quiz proceeds to alternate between showing a question and displaying the results until there are no more questions left.

After the last question result, the overall quiz result page is loaded.

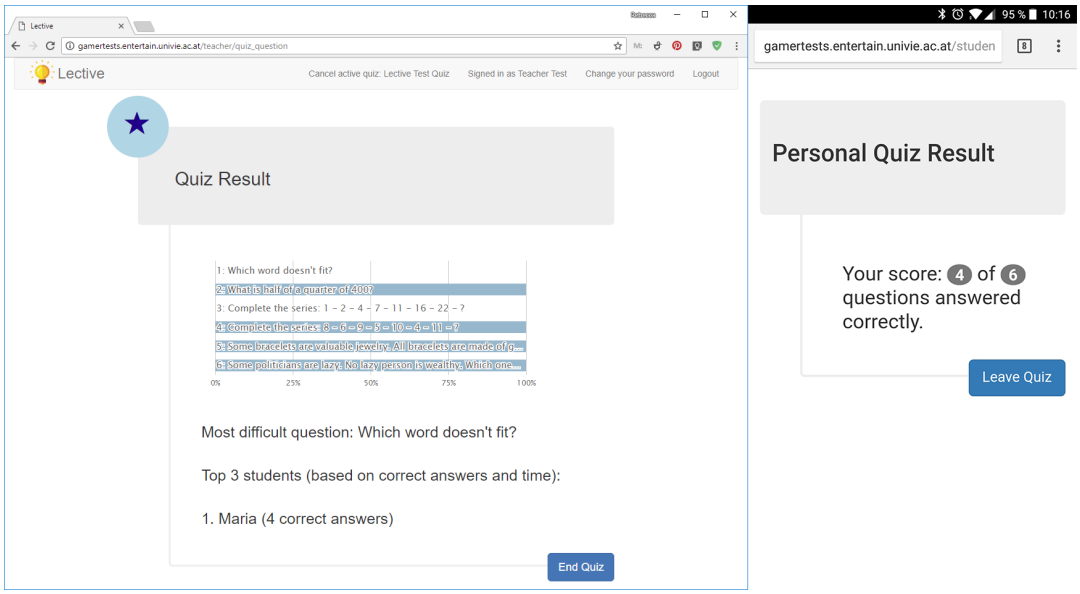


Figure 5.8: Lecturer Quiz Result page (left) and Student Quiz Result page (right).

On the lecturer's screen it consists of an "End Quiz" button and a ranking of the top three students ranked by total sum of correct answers. If there is a tie between multiple students, those students are ranked by fastest correct answers by comparing the time the given answer was saved to the database to the time the question was first displayed. The students' quiz result page displays how many questions they answered correctly out of all the questions.

5.5 Architecture and Technology Stack

As is typical of web services, Lective is built on a client-server architecture. This fulfills the requirements "cross-platform capability" and "no installation required" since the user interacts with the system via web application, which makes it platform independent. In the lecture format we propose, students bring their own devices like smartphones and laptops to the lecture ("Bring Your Own Device" policy [23]). To make sure that the layout of the Lective webpage supports the different screen resolutions and aspect ratios, it adheres to the guidelines of responsive web design [25]. The Bootstrap[3] library,

[3] `https://github.com/twbs/bootstrap`, Accessed: 2018-04-21

developed by Twitter, which was used for the prototype supports responsive design by default. The base framework that Lective was built on is called Ruby on Rails and in the following subchapter we will go into more detail on what it provides and which gems were added.

5.6 Ruby on Rails Framework

Ruby on Rails[4] is a web-application framework written in Ruby that adheres to the MVC pattern. The decision to use this framework for the Lective prototype was made for the following reasons: Ruby is an easy language to learn, the Ruby on Rails framework was built to make database-backed web-applications which is exactly what we wanted, it seemed to have an established community and came out of the box with ActionCable, a native solution for real-time functionality over WebSocket communication that had been newly introduced to Ruby on Rails with the release of version 5.

5.6.1 User Authentication With Devise

For authentication we used the Devise[5] gem, which provided most of the authentication functionality we needed out of the box. It allowed us to generate a User model and provided us with a sign up page and login page. Since most of the database columns for students and lecturers are identical, the current version of Lective uses single table inheritance to derive Student and Teacher models (in our database the lecturer's model is called "Teacher") from the Devise User model. To not confuse users of the Lective website, we've created two different sign up pages for students and lecturers, but these pages actually only differ in a hidden field containing the user type (`"student"` or `"teacher"`). Even though this field is hidden, of course accepted input is restricted to these two values in the database to prevent tampering.

[4] `http://rubyonrails.org`, Accessed: 2018-01-15
[5] `https://github.com/plataformatec/devise`, Accessed: 2018-01-23

5.6.2 WebSocket Communication With ActionCable

ActionCable allows us to define multiple so called "channels". Users who subscribe to a channel receive any message that is sent on it via Websocket connection. This was a simple solution for wanting to broadcast to multiple participants. The Lective prototype defined the following channels for real-time updates: `QuizDataChannel` for broadcasting content to all students (e.g. multiple choice answer buttons), `IndividualUpdateChannel` for sending personalized content to each student (e.g. sum of correctly answered questions), `AnswerDataChannel` for updating the lecturer's "number of answers given for current question"-counter and `OnlineStatusChannel` for updating the lecturer's "number of participants"-counter. All of the pages on the lecturer's screen are static web pages. Elements that need to be updated (e.g. the counters) are updated via Websocket when a message arrives on the `AnswerData` or `OnlineStatus` Actioncable channels. On the student's side, only the login page and the access code input page are static web pages, everything else is pushed via Websocket and updated on the current page with CoffeeScript scripts. Since the quiz does not consist of static pages on the students' side, getting back to a quiz after a disconnect was a problem. It was important to implement reconnect functionality, so a student could get back to where they left off after they log in again without having to wait for the lecturer to push the next content. Devise offers two hooks to accomplish this: overwriting the `after_sign_in_path_for(resource_or_scope)` method in the ApplicationController that is used to redirect a user to a certain page after they successfully log in and the `after_database_authentication` method in the User model that is used for executing code after successful login, but does not permit a redirect. Since a reconnecting lecturer would need to be redirected to the current static page, but a reconnecting student might not have such a static page, we needed to use both methods to achieve the desired functionality. To be able to return the correct content, both methods first check the content of the `phase` variable, that gets updated in the database each time the lecturer prompts a transition in the quiz.

The `phase` variable's states are defined as follows:

- `"0"` for the waiting page before the quiz has started;
- `"1"` for displaying the current question (determined by `current_question_index` variable in the database) on the lecturer's screen or the answer buttons on the students' screens;

- `"2"` for reconstructing the locked answer buttons with the previously selected button distinguishable on the students' screens (lecturers reconnecting in phase "2" are redirected like in phase "1"),
- `"3"` for redirecting the lecturer to the current answer page or reconstructing the locked answer buttons with the red or green tinted selection for the students,
- `"4"` for redirecting the lecturer to the overall quiz result page or displaying the personal statistics on the student's screen.

5.6.3 Visualization of Data

To create charts for the visualization of the quiz results we decided to add the Chartkick[6] gem and in the current version of Lective it is configured to use the Google Chart API[7] as its charting library. Chartkick takes arrays or hashes of information and allows us to render them in a variety of chart styles. To make the data in the database consistent, the code was changed to create given answer records for all the questions in a quiz as soon as the student joins it. All of these given answer records are initially created with the data `"No answer given."` and `"false"`, but are updated in the database each time the student selects an answer button. For the visualization of the information on how many quiz participants selected each of the offered answer options, the Lective prototype first queries the database for all the given answer records for the current question of this quiz and then groups these given answers by title and counts them. The data that is input into Chartkick is supposed to depict how many participants selected each answer option, so the array consists of two columns: `"answer title"` and `"number of occurrences"`. Bar charts were chosen as the chart style, since they allow us to present the information in a similar fashion to how the answer buttons are displayed on the students' screens. Apparently, Chartkick and the Google API do not offer the option to color one of the bars in a data series differently from the rest, which was an important feature to make the correct answer visually distinguishable from the rest of the answers. To achieve this visual characteristic the data had to be reformatted into one array per answer option and then displayed in one graph, which effectively made them four different data series and allowed us to achieve the desired coloring effect. Unfortunately, this treatment of

[6] `https://www.chartkick.com`, Accessed: 2018-01-26
[7] `https://developers.google.com/chart`, Accessed: 2018-04-19

the data also changes the thickness of the bars to be very thin and neither Chartkick nor Google Charts offers customization options to change the bar thickness back to the original width without increasing the vertical space between the bars in the chart in the same measure.

5.6.4 Database Model

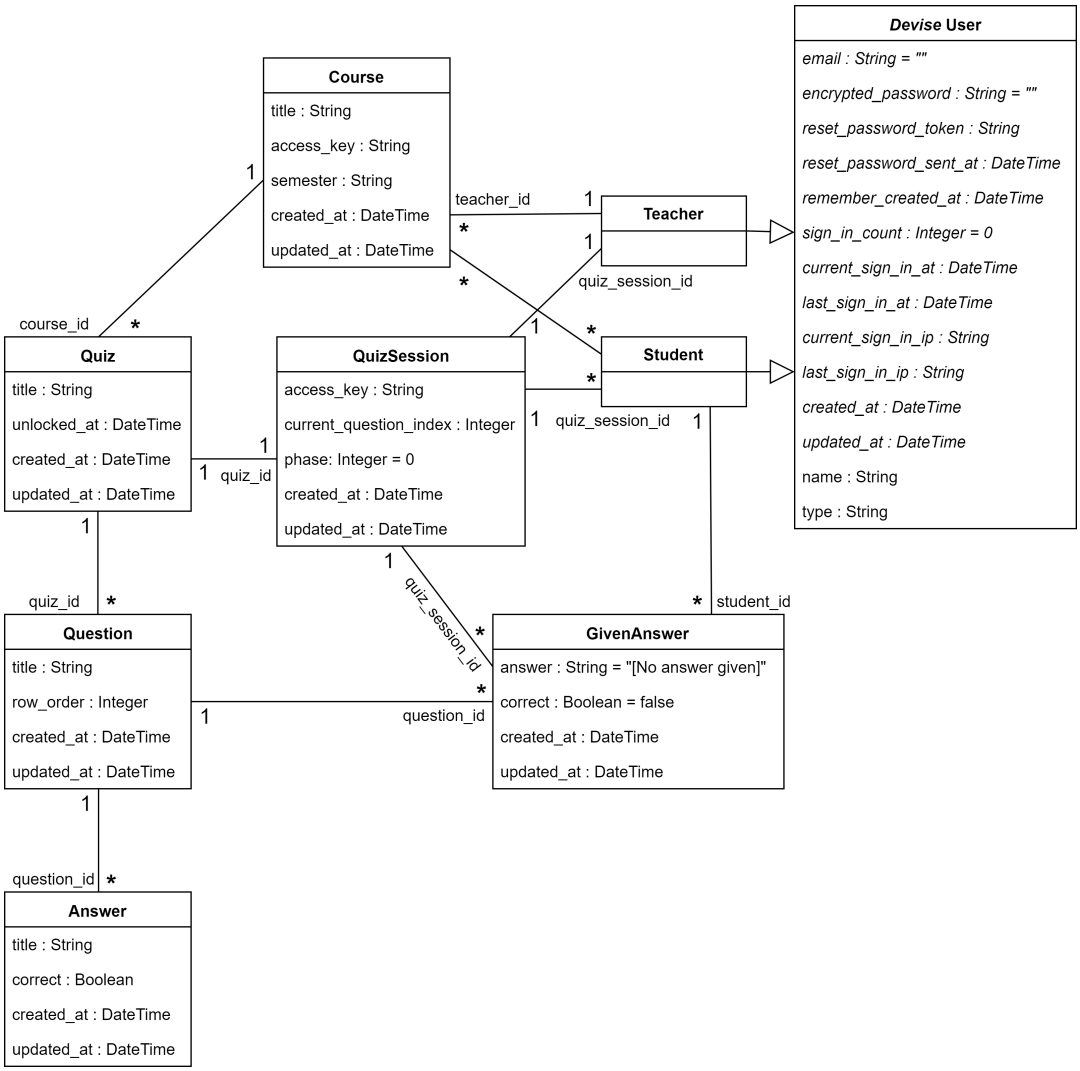


Figure 5.9: Lective Database Model.

The Lective database consists of the following models: the User model, extended through single table inheritance by the Teacher and Student models; the Course model, representing topical fields that multiple quizzes can belong to, e.g. the course "Operating Systems"

in the field of computer sciences; the Quiz model, representing sets of questions and answers the Teacher has prepared; the Question model, representing the questions the Teacher has input; the Answer model, representing the answers the Teacher has input; the QuizSession model, representing instances of a Quiz the Teacher has prepared; and the GivenAnswer model, representing the answers that were selected by the Students. For the Lective database model we started with generating a User model and corresponding controller for basic user management functionality with Devise (as described in Section 5.6.1). This generated User model was modified to include the additional fields `name` for display on leaderboards and `type` to distinguish between teacher and student users. The User model was also extended by a `quiz_session_id` field, to define the relationship between Teacher/Student and QuizSession records, since each teacher or student can only participate in one quiz at a time. As figure 5.9 shows: Each Teacher or Student can follow multiple Courses. A Course can have multiple Quizzes, a Quiz can have multiple Questions and a Question can have multiple Answers (though the current prototype limits the number of Answer options per question to 4).

5.7 Development Process

The Lective prototype was developed using an agile development [12] process approach. In each cycle a new conceptual feature was added, implemented and tested (alpha testing). After completion of the prototype an acceptance test (detailed in chapter 6) with online questionnaire was executed and last bug fixes were performed.

6 Experimental Evaluation

To assess if the Lective prototype was fit for purpose a test run of the web application was planned and an online questionnaire was created. The questionnaire's primary purpose was to explore the level of acceptance the Lective tool received from the testers to find out if it is ready to be used in a big lecture setting at the University of Vienna. We wanted to find out if the previously practised traditional form of lectures could be enhanced through gamification by utilizing the Lective quiz to increase student engagement. In the questionnaire this was investigated in particular by the following questions:

1. Did the Lective quiz successfully assess your understanding of the content? And
2. Do you think a lecture with traditional frontal teaching is preferable to a lecture teaching format with short online quiz breaks?

6.1 The Acceptance Test

A group of individuals (n=9) were invited to participate in a test run of the quiz and then provide feedback in an anonymous online questionnaire to evaluate the effectiveness of the Lective prototype. All participants had been instructed to bring their own internet-capable devices. The group used a variety of different devices for participation including Android-phones, iPhones, Windows-phones and one tester answered the questions on their PC. The test group was welcomed by this document's author, who acted as the quiz host for the test, and gave a briefing beforehand about the teaching mode that we propose: presenting a thematic block ($\tilde{3}$0min) to the students, followed by a short Lective quiz consisting of 3-4 questions to enable the students and the lecturer to assess how well the main points of the introduced thematic block have been understood. After this introduction the test group was briefed about the next steps and the technical set-up of

the test: a shared lecture-screen and their own smartphones or other, for participation. The points that were covered in the introduction were: The aim of the questionnaire: To assess if the Lective prototype was fit for purpose. What will be done with the data: It is used primarily for this Master's Thesis and for research on gamification in educational settings at the University of Vienna. Who is collecting the data: The author of this thesis[1]. And the data collection mode: Anonymous online questionnaire.

Once the test participants were ready, the quiz host navigated to the quiz start page that showed the access code for joining the test quiz session.The test subjects were asked to navigate to the Lective website at `http://gamertests.entertain.univie.ac.at` on their own devices and to sign up for a student account. When all the participants were logged in, and had input the access codes to connect their devices to the session, the quiz host started the quiz and the first question was displayed on the shared screen.

For this test a compilation of six logic questions had been selected:

1. Which word doesn't fit?

    - Smiling
    - Smelling
    - Seeing
    - Hearing

2. What is half of a quarter of 400?

    - 25
    - 50
    - 100
    - 200

3. Complete the series: 1 - 2 - 4 - 7 - 11 - 16 - 22 - ?

    - 32
    - 30
    - 29
    - 28

[1] At the University of Vienna theses must be submitted anonymously, which is why the name was removed from this paragraph. It can be found on the title page.

4. Complete the series: 8 - 6 - 9 - 5 - 10 - 4 - 11 - ?

    - 13
    - 12
    - 3
    - 2

5. Some bracelets are valuable jewelry. All bracelets are made of gold.
   Which one of the answers is true for sure?

    - Some bracelets are made of silver.
    - Some valuable jewelry is made of gold.
    - All golden bracelets are valuable.
    - All valuable jewelry are bracelets.

6. Some politicians are lazy. No lazy person is wealthy.
   Which one of the answers is true for sure?

    - Some politicians are not wealthy.
    - Some politicians are wealthy.
    - No lazy person is a politician.
    - No wealthy person is a politician.

The test ran smoothly except for one small issue, when the counter displaying how many students had answered the current question so far did not update correctly. This lead to the quiz host falsely believing that everyone had answered the question and prematurely ending the current question phase, even though two participants had not submitted an answer yet. This was also mentioned in the feedback from the online questionnaire. This issue has since been resolved. When the quiz had finished the test participants were asked to immediately take the online questionnaire.

6.2 The Online Questionnaire

The questionnaire was built to answer the following questions:

- Did the Lective web application work as intended?

- How well was the Lective prototype accepted by the target audience?
- Did the test users feel the Lective web application successfully assessed their understanding of the content?

To create the questionnaire, questions about the testers personal data, possible technical difficulties, standard user acceptance questions and questions concerning the Lective concept were formulated and combined with the help of Brinkman's "Design of a Questionnaire Instrument" [3]. Google Forms[2] was chosen to build and host the online questionnaire. To make sure that the questionnaire was easy to fill out on a smartphone's small screen, the questions were split up into groups and only one group was displayed at any given time.

In the following section we will discuss each question and the test group's responses. The question types that were chosen were a mix of single-choice, multiple-choice, rating scale and free text questions. Each multiple-choice question also gave the opportunity to input an individual answer, by using the "Other"- option, that lead to a free text field. Most of the participants completed the questionnaire on their mobile phones.

The quantitative data is presented as response totals and percentages per choice, while the qualitative data was grouped by common topics. To illustrate some of these further, we will present comments that were given by the questionnaire participants.

6.3 The Questionnaire Data

The online questionnaire started off with a short introductory text:

> *Thank you for taking the time to answer a few questions about your experience with participating in a Lective quiz. The aim of this questionnaire is to gather feedback on the Lective prototype which is intended to be used in the lecture "Operating Systems" at the University of Vienna. If you have any questions feel free to contact me at* `lective.feedback@gmail.com`.

[2] `https://www.google.com/forms/about/`, Accessed: 2018-04-30

6.3.1 General Information

Afterwards we asked about age and gender of the participant. We also wanted to know if the participants would usually bring a smartphone or other internet-capable device to a university lecture. The questions were to be answered by drop-down menu to save space on smart phone displays.

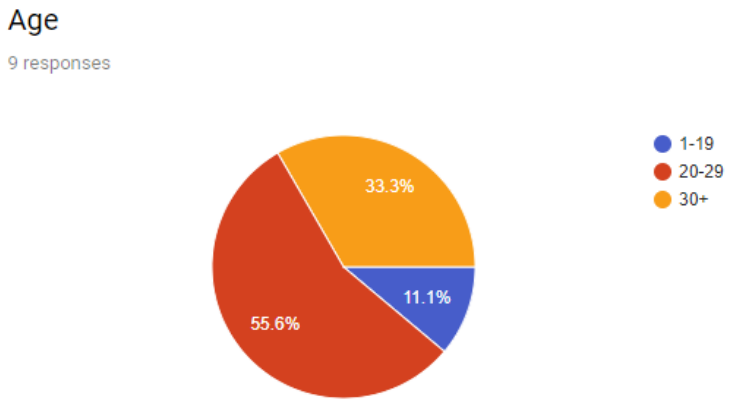


Figure 6.1: Questionnaire summary pie chart of "Age".

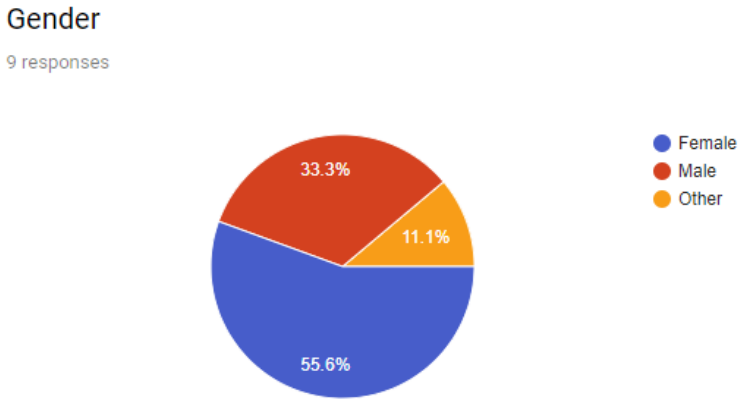


Figure 6.2: Questionnaire summary pie chart of "Gender".

Of the testers that participated in the quiz and provided feedback in the questionnaire one person was below 20, most were between 20 and 29 (n=5, 55,6%), and three were 30 and older. As for gender, 5 were female (55,6%), three male (33,3%) and one person chose "Other". When asked if they would usually bring a smartphone or other internet-capable device to a lecture, almost all answered with "Yes" (8 out of 9).

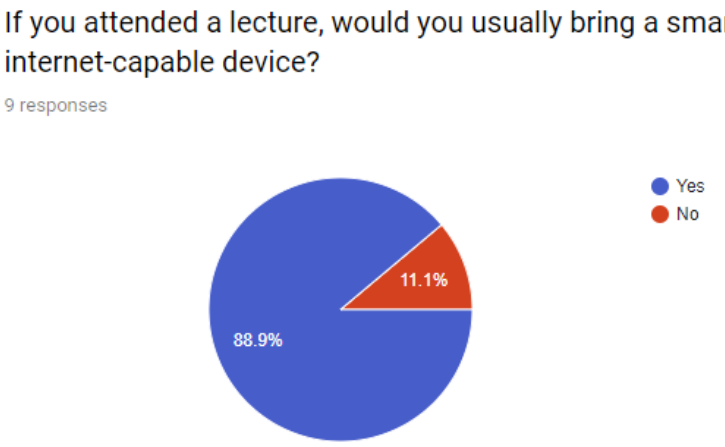


Figure 6.3: Questionnaire summary pie chart of "If you attended a lecture, would you usually bring a smartphone or other internet-capable device?".

6.3.2 Issues With the Lective Quiz Webapp

In this group we wanted to know about issues the test users might have encountered. This question was deliberately placed at the beginning of the questionnaire in the hopes that reporting an issue a user might have encountered first, would allow the test user to better separate bug reporting from rating their general user experience later, in the next question group (subsection 6.3.3). The exact question was: *"Did you encounter any issues while using Lective?"* with radio buttons (single choice) to answer *"Yes"* or *"No"*. If the user picked *"No"*, they were forwarded to the next question group, "User Experience"6.3.3. But if they answered *"Yes"*, they were asked two followup questions:

"Which of these issues was the biggest problem during your participation in the Lective quiz?" (multiple choice)

- I experienced bugs
- The website was missing features I needed
- The website was confusing to use
- The website had technical difficulties that kept me from properly participating (e.g. lag, disconnect)
- The website was visually unappealing
- Other... (Free text)

Then the test users were asked to please give a detailed description of the issues they encountered, in form of an optional open question.

Of the three people who reportet issues, two stated that they experienced bugs, specify-

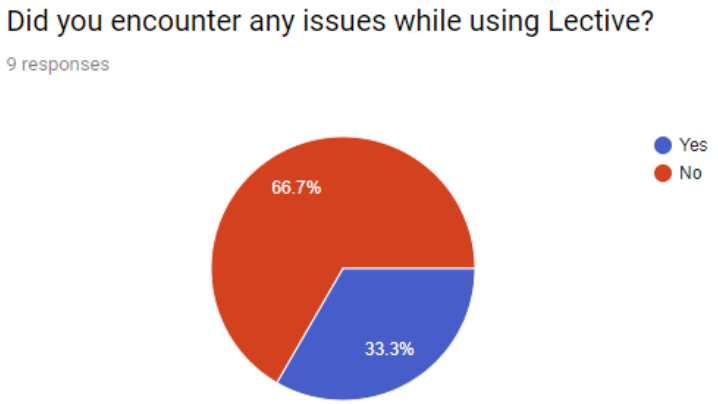


Figure 6.4: Questionnaire summary pie chart of "Which of these issues was the biggest problem during your participation in the Lective quiz?".

ing that the counter displaying how many students had answered the current question so far did not update correctly. At one point in the test run this lead to the quiz host falsely believing that everyone had answered the question and prematurely ending the current question phase, even though two participants had not submitted an answer yet. This bug has been fixed in the current version of Lective. One more person stated that they had an issue and when being asked what it was, wrote: "English? Why?". The reason we decided to keep the Lective quiz's user interface in English is that at the University of Vienna the field of Computer Science is included on the list of Master Programmes taught in English[3] and the tool needs to accommodate foreign exchange students as well.

6.3.3 User Experience

Next we wanted to know what the test users liked least about the Lective quiz and what they liked most. Both questions were to be answered by radio buttons (single choice):

"What do you like least about the Lective quiz?"

- Didn't like the questions and/or proposed answers
- Layout/design/graphical representation of the feedback
- Competition aspect
- Annoying to use
- Other... (Free text)

[3] `https://studienservice-lehrwesen.univie.ac.at/en/studying/master-programmes/degree-programmes-in-foreign-languages/#c157833`, Accessed: 2018-03-25

Even though the questions and answers of the test quiz were not part of the Lective prototype, this answer option had to be included to be able to distinguish if the user's experience had been tainted by this factor.

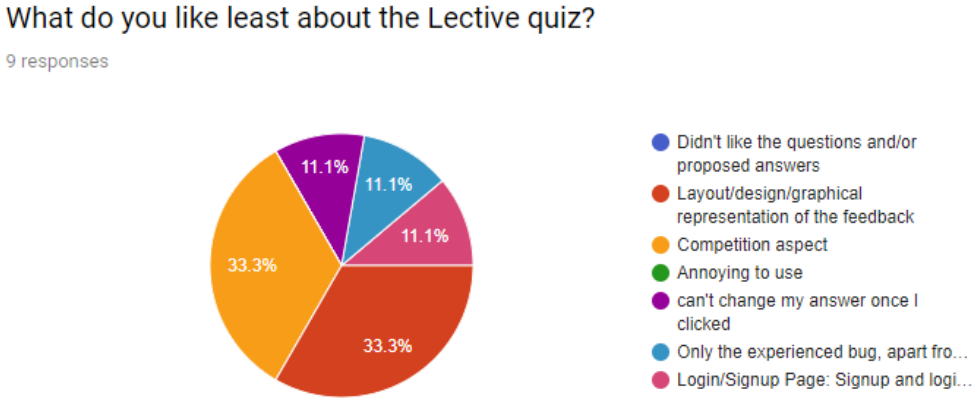


Figure 6.5: Questionnaire summary pie chart of "What do you like least about the Lective quiz?".

When answering the multiple choice question what the participants liked least about the Lective quiz, opinions differed greatly: three liked the layout/design/graphical representation of the feedback least (33,3%), three disliked the competition aspect (33,3%) and three people input their own answers respectively. One person wrote *"can't change my answer once I clicked"*, which is a feature that is provided by other educational quiz tools (as detailed in Chapter 2). Allowing to change the selection up till the point where the lecturer ends the question phase and displays the correct answer will be considered for a future version. Another person wrote *"Only the experienced bug, apart from that it is a nice idea"* referencing the students-answered-counter mentioned in the previous subsection 6.3.2. The third person wrote *"Login/Signup Page: Signup and login buttons are not really visible"* which was fixed in the current version of Lective by making them more prominent buttons.

The other question was:
"What do you like most about the Lective quiz?"

- Easy to use
- Layout/design/graphical representation of the feedback
- Interactivity vs. classical frontal teaching style
- Competition aspect
- Increasing learning through showing correct answers
- Other... (Free text)

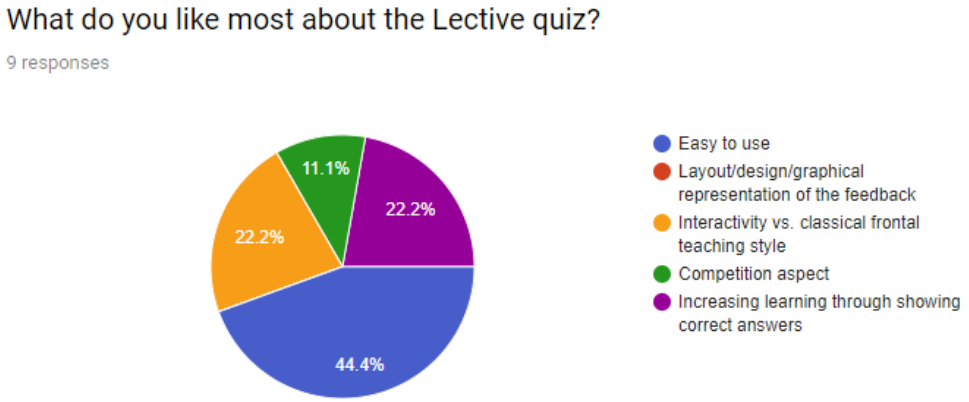


Figure 6.6: Questionnaire summary pie chart of "What do you like most about the Lective quiz?".

The question, what the test users liked most about the Lective quiz, got the following results: four liked that it was easy to use (44,4%), two liked the interactivity (22,2%), two agreed that the Lective tool increased their learning through showing correct answers (22,2%) and one tester liked the competition aspect.

6.3.4 User Satisfaction - Part I

This question group was split into two, to accommodate small screen sizes. We asked the test users to rate how satisfied they were with the Lective website on a scale of 1 ("Very dissatisfied") to 5 ("Very satisfied").

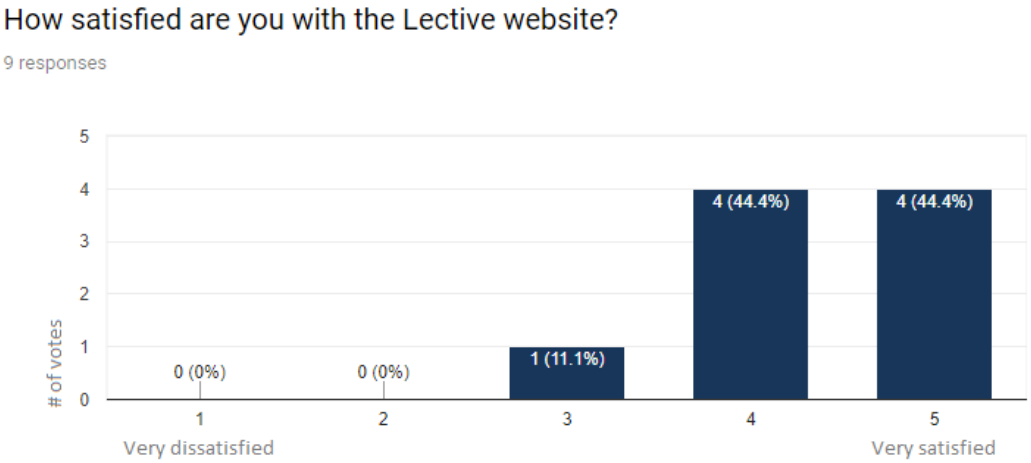


Figure 6.7: Questionnaire summary column chart of "How satisfied are you with the Lective website?".

Most test users answered either "Very satisfied" (44,4%) or "Satisfied" (44,4%) and one person voted "Neutral".

Next we asked the test participants to rate a number of the Lective Prototype's areas in a question matrix: *"Please rate the following attributes of the Lective website".*

The following areas of the Lective prototype were evaluated:

- Quality of content (questions and answers)
- Ease of navigation
- Layout/design
- Feedback on quiz performance
- Social aspect
- Fun

We chose the following 5-point bipolar scale:

- Poor
- Below average
- Average
- Good
- Excellent

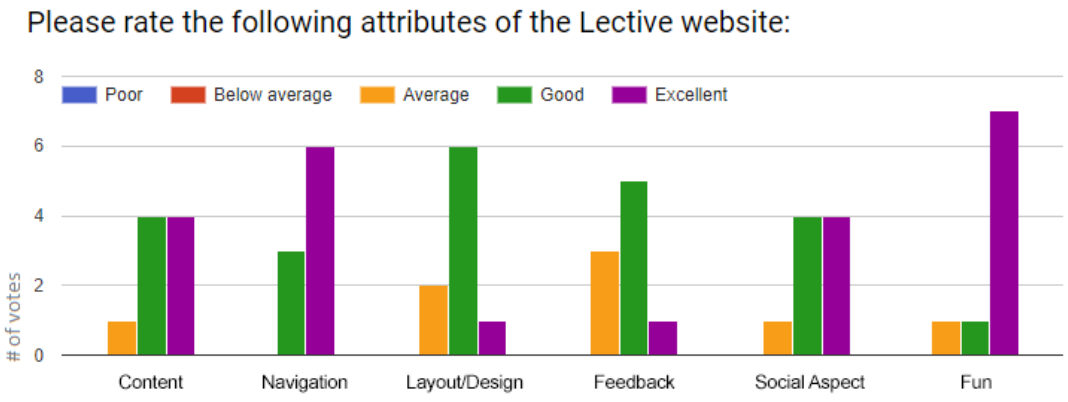


Figure 6.8: Questionnaire summary column chart of the Lective website attributes' question matrix.

Quality of the questions and answers is of course dependent on the person creating the quiz, but needed to be included in the questionnaire to be able to distinguish if a tester's possibly dissatisfactory experience rooted from their dislike of the content or their dislike of the tool's features. The collected data showed that the participants did not dislike the "Quality of content", as 8 participants rated the content to be either

"Good" or "Excellent" and one person gave it an "Average". For "Ease of navigation", all participants rated it to be either "Good" or "Excellent". "Layout/design" was voted by two users to be "Average" , by most to be "Good" (6 = 66,6%) and by one person to be "Excellent". "Feedback on quiz performance" was judged to be "Average" by three participants, "Good" by five (55,6%) and "Excellent" by one. The "Social aspect" was rated by 8 participants to be either "Good" or "Excellent". Finally, we asked the testers to rate the "Fun" they had had and almost all of them (7 = 77,7%) voted it "Excellent", one tester put down "Good" and one tester gave the Lective website an "Average". Across the board it is notable that no negative ratings were given.

6.3.5 User Satisfaction - Part II

In the second part of the user satisfaction group we asked if the user enjoyed using Lective. This was a simple yes or no question, followed by an optional open question asking what they enjoyed most using Lective.

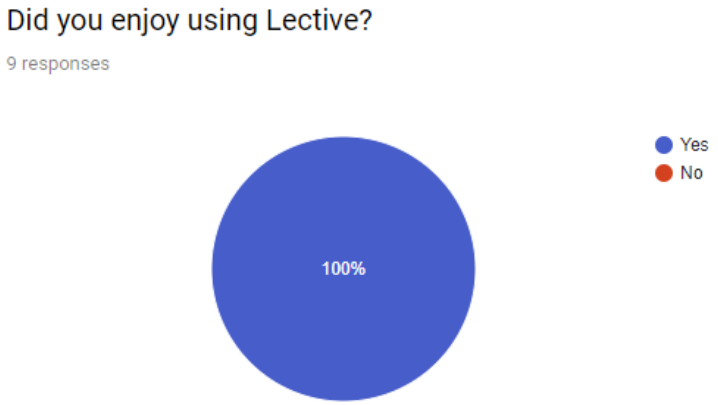


Figure 6.9: Questionnaire summary pie chart of "Did you enjoy using Lective?".

All the participants unanimously answered "Yes", they did enjoy using Lective. When asked what they enjoyed most using Lective some of the common themes of the answers were: the social aspect / competition (4 = 44,4%), the feedback / self-assessment (2 = 22,2%) and ease of use (2 = 22,2%). One other statement that was notable was; *"It was fun and when used in a lecture it would interrupt the monotony of it."*.

Lastly, we asked *"How likely are you to recommend the Lective website to a friend or colleague in the future?"*. This question was to be answered on a unipolar 5-point scale spanning from "Very unlikely" to "Very likely".

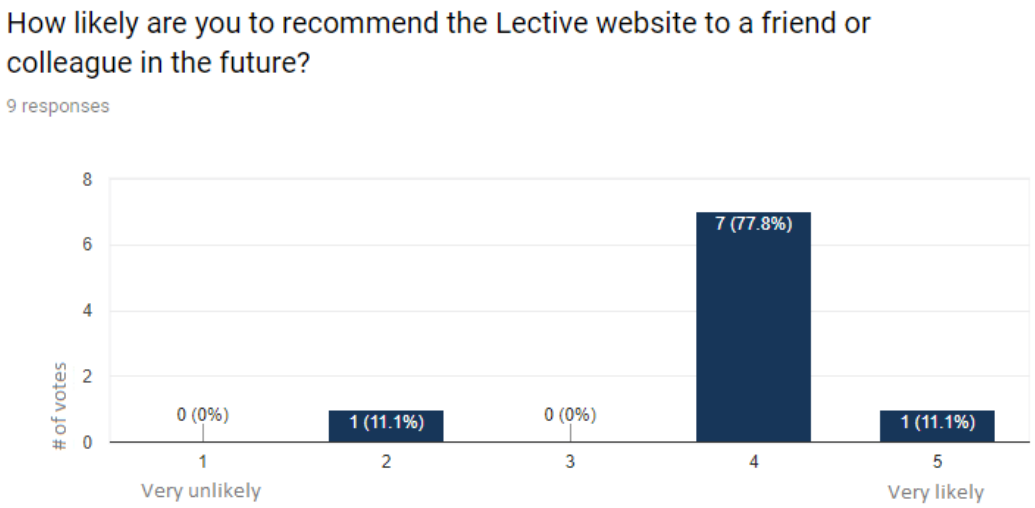


Figure 6.10: Questionnaire summary column chart of "How likely are you to recommend the Lective website to a friend or colleague in the future?".

Most ($8 = 88{,}8\%$) participants answered they were "Likely" or "Very likely" to recommend it and only one person voted that they were unlikely to recommend it.

6.3.6 Lective as an Education Tool

In this question group we wanted to know if the test users deemed the Lective prototype and the proposed teaching format valuable for university lecture settings. To get a grasp of this, we first wanted to know if they thought the tool had served its primary purpose: Assessing the student's understanding of the lecture content and giving them feedback. For this reason the first question was: *"Did the Lective quiz successfully assess your understanding of the content?"*, to be answered by selecting "Yes" or "No" from a drop down menu.

100% of the testers felt that the Lective tool's assessment had been correct. By correctly highlighting which knowledge areas were solid, and which were not, the Lective quizzes current state has satisfied its main purpose, namely giving the participants feedback on whether they need to go back and review or not, and giving the lecturer feedback on how well the latest thematic block was understood by the students or if some areas should be reiterated.

Next, we wanted to know what our test users' preferences were concerning the proposed

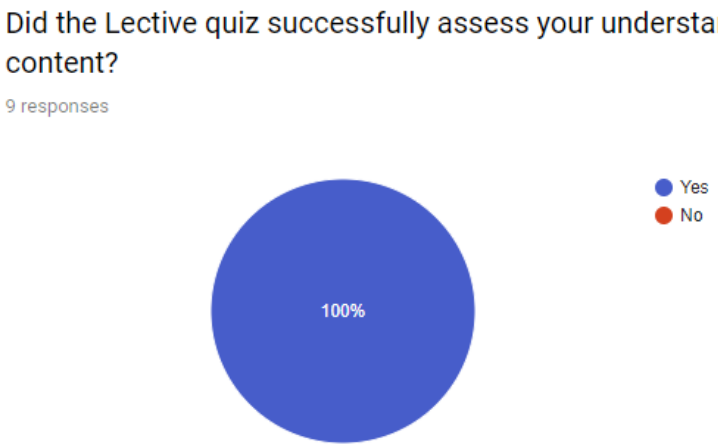


Figure 6.11: Questionnaire summary pie chart of "Did the Lective quiz successfully assess your understanding of the content?".

lecture format. This question was also in a yes or no format, to be selected from a drop down menu. The question was:

"Do you think a lecture with traditional frontal teaching is preferable to a lecture teaching format with short online quiz breaks?"

- I prefer the traditional frontal teaching lecture format.
- I prefer the lecture format with short online quiz breaks.

This question was followed by the simple optional open question: "Why?".

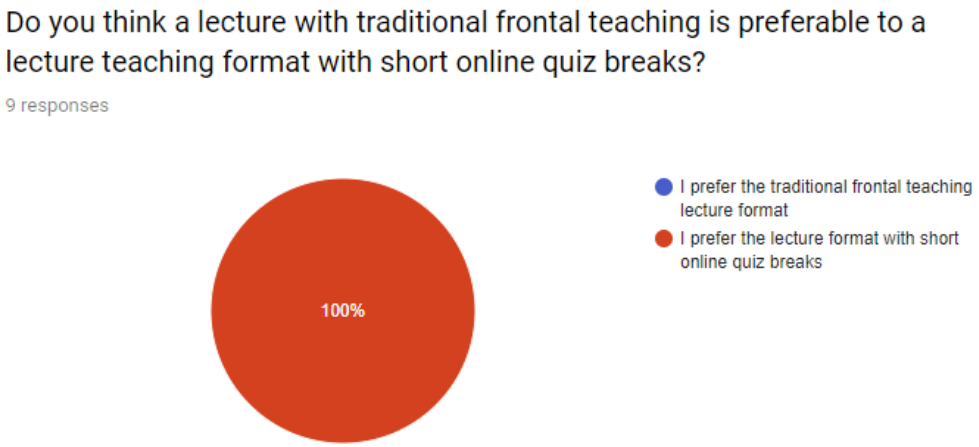


Figure 6.12: Questionnaire summary pie chart of "Do you think a lecture with traditional frontal teaching is preferable to a lecture teaching format with short online quiz breaks?".

When being asked if they thought a lecture with traditional frontal teaching is preferable

to a lecture teaching format with short online quiz breaks, all of the testers (100%) agreed that they preferred the lecture with short quiz breaks. When being asked why, the following reasons were given: easier to keep focused (6 = 66,6%), provides immediate feedback on how well the content was understood (3 = 33,3%). Some of the other keywords used in correspondence with the quiz-teaching-format were: *"fun"*, *"interactive"* and *"more interesting and engaging"*.

6.3.7 Future Improvement

Finally, we asked the testers where we need to improve most and common themes in the free text answers were: Provide enough time to answer (4 = 44,4%) and improve the feedback pages for student and lecture (3 = 33,3%). The proposed solutions from the feedback for the answer-time-issue were: "a notification before the question is evaluated" and to add a timer. Both are good ideas and being kept in mind for possible future updates. Concerning the feedback-pages-improvement the testers had a lot of great ideas: bigger bars on the lecture-screen , add a background picture to the "top 3" leaderboard, use a different library for drawing the graphs (suggestions were chartjs and canvasjs). For the individual students feedback page the suggestions were: change the height of the buttons so they are easier to select, not selected answers should have a grey background instead of blue, only display the selected answer and not the other buttons to make the correct/incorrect result more clear, display the question on the phones as well because sometimes in a lecture hall the view to the presentation screen is blocked by other people. Also, one person suggested adding an "I don't know"-button to the quiz.

A PDF version of the online questionnaire can be found at the end of this document.

7 Discussion

This chapter discusses the relevance of the proposed teaching format, a large frontal lecture with short quiz breaks. The Lective prototype will be compared to other established quiz tools and then we will discuss the strengths of the prototype in the context of our main objectives. And lastly, the outlook subsection describes limitations and possible improvements that could be made to the prototype in future updates.

7.1 Proposed Teaching Format: Large Frontal Lectures With Short Quiz Breaks

The Lective prototype is supposed to be used as an active learning activity in university lectures to periodically refresh students' attention. Our hope is that this will lead to a learning experience in which the students are more active and involved. The quiz tool is meant to be offered to students as a voluntary activity and since it is anonymous its aim is facilitating communication between students and lecturer and vice versa, not being a tool for grading student performance.

7.1.1 The Teaching Format

The teaching mode we propose starts off the lecture with a Lective quiz that immediately catches the students interest: its questions should cover the main points from the last lecture, if the content that is about to be presented builds upon that knowledge, which has the added benefit that the lecturer has the opportunity to recapitulate important points, if necessary, before delving into the new content. This repetition helps to consolidate knowledge that was absorbed in the previous lesson by recalling it from long term

memory, as detailed in chapter 3, subsection "Short Term and Long Term Memory". If there is no relevant prior content to be recapitulated, the lecture should still start with a short poll, e.g. "Which operating system do you mainly use?", to immediately grab the students attention.

The rest of the lecture should alternate between lecture segments and short Lective quiz segments. The lecture segments should be about 20-30 minutes long and cover one or more thematic blocks, e.g. in the course "Operating Systems" a lecture unit about "Process Scheduling" would start off with the thematic block "Basic Concepts and Scheduling Algorithms". The Lective quiz segments should be short and only consist of two to three questions. It is important that these questions address concepts and correlations rather than specific names, details and facts[1].

7.1.2 Advantages of the Proposed Teaching Format

This alternating lecture mode with periodic active learning activities is very promising, since it allows all students who want to to actively participate, which is usually not possible in large lecture hall settings with hundreds of students.

Participation in the online quizzes with Lective is anonymous, which might encourage more students to participate than in traditional lecture hall discussions. The fear of losing face by giving the wrong answer or saying something stupid in front of the large audience of their fellow students can be a strong inhibitor to participation in lecture hall discussions. By being able to anonymously participate with their mobile devices, this fear is not a factor anymore.

The periodic quiz breaks help the lecturer to grab the students' attention and they are likely to have a positive effect on overall student attention, as mentioned in chapter 3, subsection "Student Attention and Active Learning". The quiz breaks also make it easier for the students to not get left behind, since the repetition aspect of the quiz gives the students a chance to catch important points they might have missed in the lecture segment preceding the quiz.

Feedback from the Lective quizzes can even allow lecturers to dynamically adapt their

[1] The questions being too detail-oriented was one of the critiques the students gave us during the offline quiz described in chapter 5.1: Baseline.

lesson plan (as supported by [22]), e.g. if they notice that the current lecture topic is already known to the student audience they can decide to go through the next segments more quickly or even skip entire segments. Or in the opposite case, if the quiz results are not as good as the lecturer expected, they can decide to quickly recapitulate elements of the lecture to ensure that the key parts of the syllabus content have been understood. In addition repeating core content gives students a chance to catch up.

In our acceptance test 100% of the participants voted that they preferred a teaching format with short online quiz breaks to the traditional frontal teaching format. Other research has also shown that most students don't prefer classical frontal classroom lessons anymore: in this study [32] from 2015 only 23% of the students still preferred frontal teaching to learn theoretical material.

7.2 Comparison

This section compares the Lective prototype to the tools presented in detail in chapter 2: Related Work. This subchapter is structured by the feature groups compiled in chapter 2.

7.2.1 General Features

This subsection focuses on the general features and the similarities and differences between our findings in chapter 2 and the Lective prototype in this area.

General Features - Student

Features	Other Quiz Tools	Lective
Installation required	0%	-
Account required	0%	x
Anonymous participation	100%	x
Shared activity (synchronous)	50%	x

Table 7.1: Comparison between the Lective prototype and other tools in the feature group "General Features - Student".

Let's start with the student's perspective: None of the tools required the installation of an app, except for Kahoot! in Challenge Mode (asynchronous), which is a mode that permits giving a quiz as homework, to be completed independently by each student.

It is also noteworthy that none of the described reference quiz tools mandated sign-in, even though two out of six (33%) offered optional sign-in. With the Lective prototype we deliberately chose to make account creation mandatory, because the prototype was designed for a distinct purpose. It caters to a different audience: Other quiz tools from the education sector aim to be universally applicable to a range of different teaching environments, and for that reason the barriers to their uptake need to be especially low. Sign-in could be perceived as a barrier where the tool is intended for one-time use. The Lective prototype on the other hand was developed specifically for the lecture "Operating Systems" at the University of Vienna. Our intention for this app is for it to be a tool that is used for teaching throughout the semester, ideally in every single lecture unit. So while signing up can easily seem like too much effort for only one-time use, our intended user group would only need to sign up once to be able to use the tool many times over the course of one semester. Another benefit of having students use accounts is that it allows us to create more meaningful data sets by relating new input to previously saved data. This will allow us to give better feedback in the future, by giving students positive reinforcement when their performance improves over time.

All of the six tools let students participate anonymously in the sense that no e-mail addresses or other uniquely identifying attributes were ever displayed publicly. Lective asks students to input a nickname during sign-up, which is used for ranking students on the leaderboard. In this way Lective also provides anonymity to the participating students.

As it turns out only three of the six tools we examined in chapter 2 were designed to be a shared classroom experience in their main mode of operation. In this group, a fundamental difference in the presentation of the quiz was whether the lecturer's screen was intended to be shared with the class or not. Only one of the three tools meant for synchronous activity utilized the lecturer's screen in this way, while the other two used the lecturer's screen to display information on the students performance in real-time. For the Lective prototype we also chose the synchronous mode of experience since we wanted to empower lecturers to drive the teaching pace in a manner that maximized learning outcomes for the majority of students based on quiz results. For example we

wanted the lecturer to be able to immediately address insufficient student understanding of the subject matter if the correct response rate of a question is inadequate. Another consideration for choosing this mode was the observation that the speed with which students complete tests varies greatly and we were concerned that quicker students might be bored waiting for their peers or get distracted and miss the boat when the lesson resumes. The other half of the tools from chapter 2 were designed for asynchronous activity. Definitions of both synchronous and asynchronous classroom activity can be found in chapter 2: Related Work.

General Features - Lecturer

Features	Other Quiz Tools	Lective
Is lecturer screen meant to be shared	17%	x
Can multiple questions be run consecutively as quiz	83%	x
Share questions/quizzes	67%	-

Table 7.2: Comparison between the Lective prototype and other tools in the feature group "General Features - Lecturer".

The feature group "General Features - Lecturer", shown in table 7.2, concentrates on matters of lecturer control in terms of a tool's functionality. Five out of six tools let the lecturer group multiple questions to a quiz, so when the quiz is started the questions are asked consecutively. For the Lective prototype we chose to follow this example of question sequencing, to provide easier handling to the lecturer.

Once a quiz has been created, four of the six compared tools allow sharing it, for use by other lecturers. The current version of Lective does not support sharing since it was designed specifically for one course, the lecture "Operating Systems" at the University of Vienna, as a pilot to assess the needs and requirements of this particular environment. More information can be found in the section Limitations and Outlook.

7.2.2 Question Types

As can be seen in table 7.3, most of the tools supported the creation of single- and multiple-choice questions, and required a minimum of at least two, and a maximum of over a hundred answer options to be provided per question. For our prototype we decided to start with the most popular question type, single-choice questions and to

Question Types

Features	Other Quiz Tools	Lective
Single-choice	100%	x
Multiple-choice	83%	-
True/False	67%	-
Free text/Open question	50%	-
Sorting	33%	-
Image	33%	-

Table 7.3: Comparison between the Lective prototype and other tools in the feature group "Question Types".

support exactly four answer options per question. But the database models were created in a way that will allow us to easily add more answer options, if desired in the future.

7.2.3 Game Elements

Game Elements

Features	Other Quiz Tools	Lective
Timer	50%	-
Points	83%	-*
Leaderboard	33%	x
Rewards	50%	-

Table 7.4: Comparison between the Lective prototype and other tools in the feature group "Game Elements".

Next we compared the game elements other quiz tools incorporate with the game elements that were chosen for the Lective prototype. Three of the six compared tools used a timer during the quiz if run with standard settings, but two of these three tools provided options for turning off the timer, which also negated the impact faster answers had on awarded points. Lective does not use a timer, to let lecturers flexibly adjust the quiz pace according to the lecture plan and to the time the majority of the students take to answer each question. This was also discussed in detail in chapter 5, subsection 5.4: Lective Prototype - Process Definition.

All but one of the quiz tools gave the students points. As mentioned before, some gave

bonus points for faster answers, some gave bonus points for so called "Answer Streaks", meaning strings of consecutive correct answers. Feedbackr was the only tool that did not employ the point-mechanic in any way or form. The * in the table represents the fact that the Lective prototype does not award points, but it displays a score in the sense that it provides the information how many correct answers were given. Executing a quiz consisting of a fixed number of questions implicitly already introduces a rating system and an ultimate goal: to answer all of the questions correctly. By giving the students feedback on their performance they not only are suddenly able to compare themselves to others, but can also automatically measure themselves against the perfect score of 100%. The Lective prototype utilizes this by telling a student for example: "Your score: 3 of 5 questions answered correctly.".

Only two of the compared quiz tools made use of leaderboards. The prototype we developed incorporates a leaderboard showing the top three students on the shared screen, like a podium. Expanding on the leaderboard mechanic is being considered for a future update, as further detailed in the section Limitations and Outlook.

As far as we could tell three of the six tools gave the students rewards, which took the form of praise, a star rating, or funny pictures called memes. The Lective prototype does not give any special rewards. Expanding on this is a possibility listed in the section Limitations and Outlook.

It is noteworthy that none of the six tools we compared employed badges. The Lective prototype does not give out badges either.

7.2.4 Feedback While Quiz Is Running

Next we'll take a look at the type of feedback the commercial tools provided:

1. during the course of the quiz, which will be discussed in this subsection; and
2. as a summary after the quiz has concluded, which will be discussed in the following subsection.

Since the quiz scenario involves two different kinds of users, the teacher and the students, we also took special note of who the information was provided to.

Feedback While Quiz Is Running - Lecturer

Features	Other Quiz Tools	Lective
Hide votes until question is closed	50%	x
Total number of votes	33%	x
% of votes	0%	x
Bar chart	17%	x
Column chart	17%	-
Leaderboard	33%	x
Indicator for correct answers	17%	x

Table 7.5: Comparison between the Lective prototype and other tools in the feature group "Feedback While Quiz Is Running - Lecturer".

First, we'll take a look at the information on the lecturer's screen while the quiz is still running, as presented in table 7.5. Half of the tools waited until a question was closed to display answer distribution on the lecturer's screen, the other half updated how many participants had picked each answer option in real-time. As expected, all of the tools that immediately showed answer distribution on the lecturer's screen didn't mean for the screen to be shared with the students. More information was offered to the lecturer once a question had closed. Two out of the six tools displayed total numbers of votes per answer option on the lecturer's screen. One tool chose to represent the students' answer distribution in form of a bar chart and another tool displayed it as a column chart. Only two of the six tools implemented leaderboards and showed an update of the top scoring participants on the lecturer's screen while the quiz was running.

Now we'll take a look at the representation of data on the lecturer's screen after a question has closed. Only three tools waited with displaying information about student answer distribution and leaderboards until voting was done. Kahoot! was the only tool to give any indication of which answers from the previously asked question were correct on the lecturer's screen, which makes sense considering it is the only tool which was intended for synchronous activity and intends the lecturer's screen to be shared with the students. In the Lective prototype, since we chose to share the lecturer's screen as well, we hide the answer distribution until voting is over, so students are not influenced by which answer most other participants picked. While a question is open the prototype displays a counter that updates in real-time and indicates how many students have answered the question so far to help the lecturer decide when to proceed to the question result page. For the prototype a conscious decision was made to take advantage of the

shared screen for presenting information concerning all participants and to only display information concerning the individual participant on the student's screen. For this reason the lecturer's screen displays the total number and percentage of votes per answer option and plots this information as a bar chart. It also explicitly states "The correct answer was [A]." for example, and visually communicates this by coloring the corresponding bar green, while all other bars are grey. Even though the Lective prototype employs a leaderboard, it is only displayed once the quiz is over, and not after every question, which is something that we address in the section Limitations and Outlook.

Feedback While Quiz Is Running - Student

Features	Other Quiz Tools	Lective
Display question	83%	-
Possible to change answer	50%	-
Indicator for correct answers	100%	-
Indicator for selected answer	50%	x
Indicate if selected answer was correct	100%	x
Self-comparison with previously given answers	17%	-
Display personal score (in points)	83%	-
Display rank on leaderboard	33%	-

Table 7.6: Comparison between the Lective prototype and other tools in the feature group "Feedback While Quiz Is Running - Student".

Secondly, we also need to take a closer look at the information presented on the students' screens. Since out of all the compared tools only Kahoot!'s lecturer screen was meant to be shared with the students, it is not surprising that the other five tools display the question on the student's screen. The Lective prototype follows Kahoot!'s example in that it is meant for a shared classroom experience and thus also shares the lecturer's screen with the students. For this reason the prototype also displays the question on the shared screen, not on the students' devices. The idea behind this decision was to limit participation in the quiz to students that attend the lecture by only displaying the question on the shared screen in the lecture hall.

Half of the compared tools gave the student the option to change their answer after they had chosen an answer option. The Lective prototype currently does not implement this feature, but more information is included in the section Limitations and Outlook.

All six of the tools used the students' screens to display the information which answer option had been the correct one and if that answer option had been the one the student had selected. Only half of the tools also indicated which answer had been selected if it was incorrect. For this information the Lective prototype makes use of the two screens again: the lecturer's screen shows the correct answer while the students' screens display all the possible answers and show which answer the student had picked while also indicating if that answer was correct or not by coloring the button either green or red.

Five of the six tools implemented personal scores and gave an update of each student's new personal score on the student's screen after each question. The Lective prototype only awards points in the sense that it tells each student how many questions they answered correctly at the end of a quiz. But it does not display the students' new scores after each question.

As for the last feature "Display rank on leaderboard?": only two tools incorporated a leaderboard. Both of these tools showed the student's new rank on their screen after each question. While Lective also makes use of a leaderboard as a motivational strategy, only the final ranking after the quiz closes is displayed. The best three students, identified through their nicknames, are shown on the shared screen, but not on the students' screens.

7.2.5 Feedback After Quiz Is Done

Feedback After Quiz Is Done - Lecturer

Features	Other Quiz Tools	Lective
% of correct/incorrect votes per question	33%	x
Bar chart	33%	x
Column chart	0%	-
Leaderboard	33%	x
Detailed table of student answers	50%	-
Conclusions (e.g. "Hardest question" etc.)	33%	x
Downloadable report	67%	-

Table 7.7: Comparison between the Lective prototype and other tools in the feature group "Feedback After Quiz Is Done - Lecturer".

So far, we've had a look at the information that was displayed during the quiz, but now we'll examine how and what kind of feedback was given after the quiz session has concluded.

Only two of the quiz tools gave an overview over student accuracy, meaning percent of correct answers given, for each of the previously asked questions. This information was presented in form of a bar chart. Two other tools made use of a leaderboard on the lecturer's quiz summary page. The Lective prototype integrated both into its post-quiz summary page on the lecturer's screen: it displays a bar chart with student accuracy in percent, but also ranks the top three students overall on the leaderboard and gives the total number of correct answers for each. The bar chart is supposed to give an overview of how well the students did with each question, which has two purposes: one, each student can compare if questions that they had experienced difficulties with were also difficult for their fellow students, and two, the lecturer gets another chance to see at a glance which questions had the least correct answers, and has another chance to recapitulate and give additional explanation for those topics. As for the leaderboard: competition is a strong motivational factor. Displaying the top three students at the end of each quiz is only the first step in Lective's strategy to get students involved through competitive motivational strategies. The section Limitations and Outlook contains a suggestion for the next step and describes the benefits of also adding the display of each student's personal rank after each question.

Half of the quiz tools we compared gave the lecturer a detailed table of which student answered which question correctly or incorrectly. The Lective prototype currently does not provide this information to the lecturer since we think that summary data, like "Toughest Question" etc., is more informative without compromising the students' anonymity.

Two of the tools drew conclusions from the students' answer data, e.g. Quizizz displays the answer with the lowest accuracy as the "Toughest Question" and the question students took longest to answer as the "Longest Question". Lective also displays the "Most Difficult Question", unless all questions were answered correctly by more than 75% of the students, in which case the reasoning is that none of the questions could be considered difficult for the current student audience.

Four of the six tools offered the lecturer some sort of downloadable report with data

on the students' performance. Lective does not provide a downloadable report feature, but since the Lective web service is currently running on a university server and was developed in-house, it can be customized to have future updates include any form of data analysis desired, especially concerning long term performance development of individual students.

Feedback After Quiz Is Done - Student

Features	Other Quiz Tools	Lective
Detailed table of student's answers	50%	-
List of questions with correct answers	50%	-
Display personal score (in points)	50%	-
Display personal score (in total questions correct)	67%	x
Display personal accuracy (% correct)	50%	-
Display personal rank on leaderboard	33%	-

Table 7.8: Comparison between the Lective prototype and other tools in the feature group "Feedback After Quiz Is Done - Student".

Now that we've compared data on the lecturer's screen, we'll take a look at the information provided to the students at the point after a quiz session is done.

Half of the compared tools provide a table to each individual student listing each question and the student's chosen answers. Furthermore, they clearly indicate whether the chosen answers were correct, and if not, provide the correct answers. Lective does not provide this information to the student, but giving each student an overview of all their answers and letting them review themselves is a feature with benefits that are discussed in the section Limitations and Outlook.

Three of the compared ARS tools gave each student a personal point-score, that was calculated by awarding a certain number of points per correctly answered question and sometimes by also factoring in how quickly these questions had been answered. Four tools gave the students scores in total numbers of correct answers, e.g. "3 out of 5 correct" or "3 correct, 2 incorrect". Only two of these tools used points to rank students on a leaderboard, which was displayed on the students' screens. Three of the six tools also gave students their personal accuracy rating. The Lective prototype does not employ a timer or factor answer time into a point-based score for the students. Instead it gives each student the feedback how many questions they answered correctly and how many questions there were in total. The leaderboard with the top three students is

only displayed on the shared lecturer's screen, not on the students' screens, and the prototype to date does not provide each student's personal rank, but the positive effect on motivation such a feature could have is included in the section Limitations and Outlook.

7.3 Strengths

The Lective prototype has delivered a free to use gamified audience response system developed specifically for the lecture "Operating Systems" at the University of Vienna. Its main benefits are that is has the potential to increase learning, attention and motivation and transforms the classical frontal lecture style into an interactive learning experience. These benefits may positively impact students at no additional cost to the University.

In the following we will show how using the Lective prototype in the teaching format we proposed at the beginning of this thesis meets the goal of empowering the lecturer by letting them:

- determine how well the information that was just presented has been absorbed by the students;
- enhance student learning, including addressing common deficits in real-time;
- increase students' attention; and
- motivate students to be interested and invested in the lecture.

7.3.1 Mechanisms to Assess Level of Student Learning

In the traditional chalk and talk frontal teaching format information only flows one way: from lecturer to students. By using the Lective online quiz, the quiz results also permit the flow of information in the other direction: from students to lecturer. By paying attention to the percentage of correct answers included in the results for each quiz question the lecturer can identify weak points in the students' understanding of the lecture content and can give a short recapitulation of the main facts if needed, or even dynamically adjust the lesson plan to better fit the student audience. In the online questionnaire that was completed by our test group, 100% of the participants agreed

that the prototype successfully assessed their understanding of the content.

7.3.2 Enhance Student Learning, Including Addressing Common Deficits in Real-Time

Another strong point of using the Lective prototype in lectures is that the repetition during the quiz is beneficial to the students' retention of the lecture content. If used in the proposed lecture format it even covers two phases: immediate repetition to catch important points one might have missed during the lecture, since attention has been observed to follow a pattern with short breaks every few minutes [5], and repetition at the start of the next lecture unit, which in most cases is in the following week. The memory theory by Waugh and Norman, that we expanded on in chapter 3 states that repetition of information helps to transfer newly absorbed information from short term memory to long term memory. The theory by Unsworth and Engle claims that recalling information, as we do when we try to remember the correct answer to a question, often involves accessing long term memory and short term memory, even when the information had been absorbed only a short while ago. Studies have confirmed that using an ARS enhances student learning [36] [17] [27] [35].

7.3.3 Increase Students' Attention

Having the students participate in an online quiz like Lective is a lecture-wide social active learning activity. As mentioned before in chapter 3, active learning activities are great at grabbing students' attention and have a positive effect on overall attention that even lasts into the next lecture period directly after the quiz [5].

7.3.4 Motivate Students to Be Interested and Invested in the Lecture

It is intended, that using the Lective prototype in the teaching format we proposed at the beginning of this chapter will increase students' motivation by making the lecture hall a learning environment that meets the three key needs for optimal functioning

detailed by the Self-Determination Theory: competence, autonomy and relatedness. When these needs are met, the students can start to enjoy the activity and feel proud of their achievements. We hope to boost the students' feelings of competence by giving them positive feedback for each correctly answered question. Increasing the feeling of autonomy in a lecture hall with potentially hundreds of students is a tough task, but giving the students the opportunity to participate in a quiz with more than one answer option to choose from while answering questions could be seen as giving the students more autonomy than just listening to a talk would. As for relatedness: it is very likely that participating in the same quiz with their fellow students and competing against them for a spot on the leaderboard will increase their feeling of relatedness. For this reason we think that using the Lective prototype in lectures might have a positive impact on student motivation and that using the aforementioned proposed teaching format might even increase attendance numbers for lectures where attendance is not mandatory.

7.3.5 Technical Considerations

In the rest of this chapter we will show that the Lective prototype has met or exceeded all of the requirements we had set for it in the conceptual phase and why this is beneficial.

The first two requirements "Cross-platform capabilities" and "No installation required" were met by developing Lective as a web service. This is a strong point compared to other services and tools because it means that Lective can run in the browser of any contemporary internet-capable device.

The user acceptance test in chapter 6 gave very positive feedback, with 100% of the test subjects agreeing that they enjoyed using Lective, and almost half of the testers voting that ease of use was what they liked most about the prototype. This means that the third requirement, "Simple web-based user interface" has also successfully been met. This is also shown in the fact that all of our test audience assessed "ease of navigation" to be good or excellent and almost everyone voted the level of "fun" to be excellent as well. From these results we are confident that using the Lective prototype in a lecture would likely increase student engagement and learning, by making lectures more interactive and enjoyable. In the conceptual phase of developing the Lective prototype, we had decided to let students join quizzes anonymously, by representing students on

the leaderboard with their chosen nicknames. This demonstrates that the prototype has met the fourth requirement, "Semi-anonymous voting", which is positive because this way quiz performance can not be used to impact a student's grade. In keeping with this idea, Lective is meant to be used as a tool with voluntary participation, in the hopes that the students will find enough value in joining the activity and being able to self-assess their knowledge to be motivated to do so without extrinsic reward.

In the online questionnaire that was completed by our test group, 100% of the participants agreed that the prototype successfully assessed their understanding of the content. This proves that the Lective prototype successfully fulfilled one of its main purposes. Because accurate performance assessment is the requirement to being able to give meaningful feedback, which supports learning.

By requiring students to create accounts, we have also met our last requirement, which has enabled the Lective prototype to group data sets by student and thus more meaningfully link the data.

7.4 Limitations and Outlook

This chapter explores limitations and future outlook. While the Lective prototype is fit for purpose, as mentioned in the subchapter Comparison above, the following potential future updates have been identified that could be implemented to further enhance and expand the functionality. These improvements can be grouped into the following categories:

- Mechanisms to assess level of student learning
- Empowering the teacher
- Methods to increase student attention
- Empowering the student and increasing motivation
- Providing the potential of expansion to other lectures

7.4.1 Mechanisms to Assess Level of Student Learning

For future work we highly recommend that a study is conducted in which Lective is used in the course "Operating Systems" with the same questions and conditions that were used in the offline quiz described in chapter 5, subsection: Baseline. This would give additional data on how much the use of Lective in a lecture context influences student engagement, learning and attendance and would further empower the lecturer to recognize when subject matter should be further explained.

For the development of this beta version of Lective we have conducted an acceptance test focusing on the needs of the students. Before further development we recommend conducting acceptance testing among lecturers in higher education environments as well. It stands to reason that lecturers from different backgrounds will have different preferences, so tests in this area could explore how the lecturers' levels of technical adeptness and their backgrounds in different fields of study influence each lecturer's preferences and if there are any particular desirable features that are absent for a majority of lecturers. A lecturer acceptance test would also make sure that not only the students feel that the Lective application correctly assesses their level of understanding, but also that the lecturers feel that the information on student performance is presented in a clear way and highlights the appropriate statistics and data correlations.

Before the Lective prototype is applied to a large lecture hall setting with hundreds of students, we recommend further performance tests to be done, including a stress test[2], to make sure the prototype is ready for use.

7.4.2 Empowering the Teacher

Assessing learning success in real-time

What this thesis hasn't explored is how the lecturer would recognize and address deficits in learning that affect a large proportion of attendees. There is a potential opportunity to expand the scope of this work. Questions that could potentially be addressed are:

[2]A stress test is a test that observes how a system handles an increasing number of simultaneous requests with the goal to find the point where performance is degraded, or even the point of complete system failure. It is a benchmark for system performance.

- Characterizing what constitutes a deficit in learning across a substantial proportion of students
- Developing an appropriate response to addressing this deficit, taking available time and staff resources into account

Collaborating with other lecturers

A very popular feature that the prototype is currently missing is the option for lecturers to share quizzes they created with other lecturers. For a future update we are considering putting quizzes into three modes: private, if the quiz is not meant to be shared; shared, if the quiz is only meant to be shared by invite; and public, to be assigned a category and tagged by keywords, so it can be found by using the Lective quiz search.

7.4.3 Methods to Increase Student Attention

To quantify the potential of the Lective prototype to increase student attention the following test could be run as part of a live lecture with short Lective quiz breaks: Following the example of the test conducted by Bunce et al. [5] one possibility would be to distribute clickers to the students and instruct them to use these to record self-perceived lapses in attention. The purpose of this test would be to gather data that could be analyzed to see if the occurrence of attention lapses decreases when using our proposed lecture format as opposed to the traditional frontal lecture format.

Another possibility would be to collect data on students' perception of their own attention by questionnaire that is distributed at the end of the lecture.

7.4.4 Empowering the Student and Increasing Motivation

Applying the Self-Determination Theory from chapter 3 to the lecture context to make the students feel comfortable enough to enjoy what they are doing, made us come up with the following additional features that could be used to improve Lective online quizzes:

- To increase the feeling of Autonomy: Allow students to change their selected answer option as long as the question is open. This is an easy fix to eliminate students' frustration in the case they changed their mind on which answer option

they want to submit.

- To increase the feeling of Competence: Add positive feedback after a student has answered a question correctly. Could be a simple sentence of praise, like "Well done!" or "You're on a roll!". Praise in particular has proven to be an effective motivator for adults [7]. Ideally add some good natured humour, since according to Baid and Lambert humour can have a positive impact on learning situations [1].

- To increase the feeling of Competence: After a quiz is done show each student a list of all the quizzes questions and the information which answer they had chosen, if it was correct, and if not what the correct answer was. Ideally make it a sorted list with incorrectly answered questions at the top. Being presented with this information has huge pedagogical value, since it gives the student positive reinforcement for all the questions they answered correctly, but also gives them the chance to independently review those questions, that they got wrong and take another look at the correct answers.

- To increase the feeling of Relatedness: Display each student's personal rank on the leaderboard on their screen after each quiz question and show them their final rank after the quiz is done. This would increase the competition aspect and make students consider their performance in relation to their peers, thus motivating students that like to compete.

As detailed in the subchapter Strengths, the Lective prototype incorporates multiple features that are intended to increase student motivation, like the competitive aspect of the quiz. But since there are different types of students with different preferences, it stands to reason that there are also those that don't respond well to the competitive aspect, e.g. if they feel that they always fall short. So how can we try to motivate those students too? One possible way would be to emphasize self-improvement. By making students sign up with a permanent account on the Lective website we have lain the groundwork for introducing features that analyze student performance data over multiple sessions and motivate students by giving them positive reinforcement when their performance improves over time. This opens the door for a whole range of features that give students positive reinforcement, from setting achievable goals to giving out badges for achievements from the general education sector (e.g. "Smartypants Badge for 50 correctly answered questions!" or "Brainwave Badge for 10 correct answers in

a row!"). This information could for instance be incorporated into the existing quiz results summary. But allowing for self-comparison could also take the simple form of allowing the student to retake quizzes they previously participated in on the following day. This feature would give students the freedom to experiment with the answer options without having to worry too much about getting it wrong the first time. This repeat feature should give the student the information how they did last time, in addition to the result from the current attempt, so the student can track their own progress and identify questions that are still difficult. A feature like this would also add another cycle of optional repetition, to help transfer the main points of the lecture content to the students' long term memory.

7.4.5 General Limitations

Most students have a mobile device and use it everyday [32]. In fact, 89% of participants of our acceptance test group stated that they would usually bring their smartphones or another internet-capable device when they attend lectures. However, those students who are not willing or able to handle mobile devices or online services would not be able to participate in the quiz and would be excluded [19] unless another student let them share their device. Considering the outcome of the test group, it is unlikely that a large number of students would be excluded from the quiz on the basis of not bringing a mobile device.

Another limitation might be that students need to create an account to be able to participate in Lective classroom quizzes. Though there are also benefits as mentioned in the subchapter 7.3: Strengths. A better solution would be to let students join by only inputting a session key on the Lective website, and asking them after the quiz is over if they would like to sign up or log in to save their data and receive more meaningful feedback in the future. This change is being considered for a future update.

Currently the code that students use to connect to a particular Lective quiz session after logging in is a eight character hex code consisting of letters and digits. As it turns out this combination can be very tedious to input on a mobile phone, since most on-screen keyboards don't have keys for numbers and letters on the same page, which leads to constant switching between menus. It would be better to adapt a code like the ones Kahoot! uses: a game pin consisting only of numbers, which is much easier to input.

The user acceptance test provided us with the insight that putting control of the pacing of the quiz completely into the lecturer's hands leads to the students sometimes being surprised and feeling frustrated if they did not manage to select an answer in time. A very reasonable solution to this problem was provided by one of our test users: after the lecturer clicks the "Next" button, we should incorporate a short delay during which the students are notified that time is almost up before actually stopping to accept answers.

Another point that could be improved in Lective is the representation of feedback. The test-users in our acceptance test suggested making the information represented by the bar chart more visible by increasing bar thickness, or since the library currently used for creating the bar charts doesn't seem to support that, using a different library altogether.

7.4.6 Technical Limitations

Ruby on Rails has a few limitations of its own, the main one being runtime speed and performance at large application scales. While we haven't noticed any delays or other issues with runtime during development or during the acceptance test, this might be a possible bottleneck in the future, if Lective is adopted by multiple lectures with lecturers and their hundreds of students using the web service at the same time.

Issues with ActionCable on the other hand have become apparent even while the prototype was still in development: For one, ActionCable provides no means to catch up on messages that were sent while a client was disconnected. As long as a connection is intact, it has a state that is stored on the server-side. But any loss of connectivity that causes the client to reconnect will result in the server discarding the Channel object for the old connection, and information on the state with it. Secondly, ActionCable provides no acknowledgement of success or failure for the publishing of messages from a client to the ActionCable server. Which could potentially lead to a lot of frustration if a lecturer presses the button to switch to the next question, the new page is loaded on his screen, but the answer options are never sent to the students and no one can participate.

7.4.7 Providing the Potential of Expansion to Other Lectures

While the Lective prototype is closely tailored to the lecture hall environment, the lecture format and the preferences of the teaching staff of the course "Operating Systems" at the University of Vienna, it can be easily customized and expanded to meet additional requirements of other courses. The prototype was developed in a way that permits the restructuring of the user interface as well as the addition of new features with reasonable effort. In this way, future versions of Lective will be ready for use in any course that would draw a benefit from having their students participate in online quizzes.

8 Conclusion

In this thesis, it was shown that it is possible to create a quiz application for a specific lecture that uses gamification elements to enhance the traditional university lecture format with potential to empower the lecturer and increase students' attention, motivation and learning.

The result of this work is the Lective prototype, a web application built on the Ruby on Rails framework. It is an online quiz tool, which lets lecturers create their own content and is intended to be used in higher education lectures as an activity in which the whole lecture hall can participate by their own devices. This thesis also proposes a lecture format in which 30 minutes of frontal lecture alternate with short online quizzes using the Lective web platform (chapter 7). In the scope of this master's thesis, data about the current state of higher education lectures at the University of Vienna was gathered using the example of the course "Operating Systems" (chapter 5). Building on this information the concept for the Lective tool was developed, the prototype was built and a user acceptance test was conducted (chapter 6), which returned mostly positive results.

The Lective prototype addresses similar principles as the other six quiz tools that we compared (chapter 2):

- No dedicated hardware required
- No installation required
- Anonymous participation
- Gamification elements
- Empowers lecturer by providing feedback in real-time while quiz is running

The scope of this thesis covered the implementation of the basic features of a gamified quiz tool. There are additional enhancements to the prototype that could be explored as part of future work moving towards large-scale professional use, and these are discussed

in the subchapter "Limitations and Outlook" of the discussion (chapter 7).

While the prototype makes use of the gamification elements "Points" and "Leaderboard", "Rewards" are an additional gamification method that is used by half of the other quiz tools, which could be a valuable expansion to increase student motivation as part of future work. A "Timer" ending the scheduled question response time was employed by half of the comparable quiz tools, but wasn't implemented as part of the prototype in favor of putting control of the pacing of the quiz completely into the lecturer's hands, allowing the lecturer to drive question pace based on observation of student engagement and the planned lecture structure.

The currently implemented gamification elements are not exhaustive, and significant additional gamification could be included in the existing prototype by using the data generated in a given quiz session and comparing it against long term data for each individual student. This could boost the student's feeling of competence, by showing them how they have improved over time, which according to the Self-Determination Theory (chapter 3) is one of the three inherent psychological needs that must be satisfied to create an environment for optimal functioning, which in turn fosters intrinsic motivation.

Concluding this work it can be said that while the Lective prototype's effectiveness could be increased by adding and enhancing gamification features, and while we would advise conducting a stress test before employing the prototype to large lectures with hundreds of students, the user acceptance test has not found any major issues and has returned positive results in terms of user satisfaction.

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Abstract

Currently higher education lectures often still default to the traditional frontal teaching format, even though pedagogical research suggests more interactive teaching formats to be more effective. The goal of this thesis is to create a quiz tool for the use in higher education frontal classroom lectures with the purpose of introducing a non-intrusive feedback channel. The anticipated advantages of such a tool are two-fold: it provides the lecturer with information on how well the lecture content was understood by the students in real-time and it positively impacts student attention, motivation and learning by adding gamification to the traditional lecture format. The Lective project was designed for this purpose and a prototype was developed and tested. The theoretical background, application concept, development steps, technical information and testing results are documented in this thesis.

Zusammenfassung

Heutzutage werden Universitätsvorlesungen oft noch im traditionellen Frontalunterrichtsformat gehalten, obwohl pädagogische Studien nahelegen, dass interaktivere Unterrichtsformate besser geeignet wären. Das Ziel dieser Arbeit ist es ein Quiztool für Universitätvorlesungen zu schaffen, das dem Frontalunterricht einen Feedback-Kanal hinzufügt ohne den Unterricht zu behindern. Von einer solchen Applikation erwarten wir uns zwei große Vorteile: einerseits gibt es dem Vortragenden in Echtzeit Informationen darüber wie gut der Vortragsinhalt von den Studenten verstanden wurde, und andererseits wird durch die Verwendung von Gamification bei den Studenten die Aufmerksamkeit, Motivation und die Aufnahme von neuen Inhalten verbessert. Das Lective Projekt hat zu diesem Zweck eine Applikation konzipiert, und einen Prototypen entwickelt und getestet. Diese Masterarbeit enthält den theoretischen Hintergrund, das Konzept der Applikation und seiner Anwendung, die Entwicklungsschritte, die technischen Informationen und die Ergebnisse der durchgeführten Tests.

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Appendix I:
Baseline Test - Offline Questionnaires

This appendix contains the paper tests that were distributed in the course "Operating Systems" at the University of Vienna on the following dates:

2017-03-31 - Lecture Unit	5's	Topic: Scheduling
2017-04-07 - Lecture Unit	6's	Topic: Process Scheduling
2017-05-05 - Lecture Unit	8's	Topic: Memory Management
2017-05-12 - Lecture Unit	9's	Topic: Mass Storage
2017-05-19 - Lecture Unit	10's	Topic: I/O Systems

More information on these tests and their results can be found in chapter 5: "Implementation" - subchapter "Baseline".

VO BETRIEBSSYSTEME SS17 - #5: SCHEDULING

INSTRUCTIONS

This test is provided to you as part of a pilot with the goal to improve the students learning experience by making lectures more interactive. It gives you the opportunity to assess how much of the lecture you've understood and remembered.

This test will **NOT be graded**. The form will ask you to specify your gender and age for statistical purposes. The test is anonymous and giving a name is not required.

The solutions will be revealed following the collection of the completed forms.

ABOUT YOU

Gender: Age:

QUESTIONS

Please check the correct answers for each question.

1) **Which of the following is true of cooperative scheduling?**

- ☐ a. It requires a timer.
- ☐ b. A process keeps the CPU until it releases the CPU either by terminating or by switching to the waiting state.
- ☐ c. It incurs a cost associated with access to shared data.
- ☐ d. A process switches from the running state to the ready state when an interrupt occurs.

2) **_____ is the number of processes that are completed per time unit.**

- ☐ a. CPU utilization
- ☐ b. Response time
- ☐ c. Turnaround time
- ☐ d. Throughput

3) **Which of the following is true of multilevel queue scheduling?**

- ☐ a. Processes can move between queues.
- ☐ b. Each queue has its own scheduling algorithm.
- ☐ c. A queue cannot have absolute priority over lower-priority queues.
- ☐ d. It is the most general CPU-scheduling algorithm.

4) **_____ involves the decision of which kernel thread to schedule onto which CPU.**

- ☐ a. Process-contention scope
- ☐ b. System-contention scope
- ☐ c. Dispatcher
- ☐ d. Round-robin scheduling

5) **The two general approaches to load balancing are _____ and _____.**

- ☐ a. soft affinity, hard affinity
- ☐ b. coarse grained, fine grained
- ☐ c. soft real-time, hard real-time
- ☐ d. push migration, pull migration

6) **A significant problem with priority scheduling algorithms is _____.**

- ☐ a. complexity
- ☐ b. starvation
- ☐ c. determining the length of the next CPU burst
- ☐ d. determining the length of the time quantum

7) **The rate of a periodic task in a hard real-time system is ___, where p is a period and t is the processing time.**

- ☐ a. 1/p
- ☐ b. p/t
- ☐ c. 1/t
- ☐ d. pt

8) **Little's formula calculates the _____, dependent on average arrival rate and average waiting time.**

- ☐ a. average number of processes in a queue
- ☐ b. average number of processes per second
- ☐ c. average distribution time
- ☐ d. average CPU utilization

SURVEY

Did this test help you identify which areas of the lecture you've understood and remembered and which areas might need reviewing?

VO BETRIEBSSYSTEME SS17 - #6: PROCESS SCHEDULING

INSTRUCTIONS

This test is provided to you as part of a pilot with the goal to improve the students learning experience by making lectures more interactive. It gives you the opportunity to assess how much of the lecture you've understood and remembered.

This test will **NOT be graded**. The form will ask you to specify your gender and age for statistical purposes. The test is anonymous and giving a name is not required.

The solutions will be revealed following the collection of the completed forms.

ABOUT YOU

Gender: Age:

QUESTIONS

Please check the correct answers for each question.

1) **A race condition …**

- ☐ a. …results when several threads try to access the same data concurrently.
- ☐ b. ...results when several threads try to access and modify the same data concurrently.
- ☐ c. ...will result only if the outcome of execution does not depend on the order in which instructions are executed.
- ☐ d. None of the above.

2) **A(n) _____ refers to where a process is accessing/updating shared data.**

- ☐ a. critical section
- ☐ b. entry section
- ☐ c. mutex
- ☐ d. test-and-set

3) **A solution to the critical section problem <u>does NOT</u> have to satisfy which of the following requirements?**

- ☐ a. mutual exclusion
- ☐ b. progress
- ☐ c. atomicity
- ☐ d. bounded waiting

4) **A counting semaphore …**

- ☐ a. …is essentially an integer variable.
- ☐ b. …is accessed through only one standard operation.
- ☐ c. …can be modified simultaneously by multiple threads.
- ☐ d. …cannot be used to control access to a thread's critical sections.

5) **A mutex lock…**

- ☐ a. …is exactly like a counting semaphore.
- ☐ b. …is essentially a boolean variable.
- ☐ c. …is not guaranteed to be atomic.
- ☐ d. …can be used to eliminate busy waiting.

6) **What is the correct order of operations for protecting a critical section using <u>mutex locks</u>?**

- ☐ a. *`release()`* followed by *`acquire()`*
- ☐ b. *`acquire()`* followed by *`release()`*
- ☐ c. *`wait()`* followed by *`signal()`*
- ☐ d. *`signal()`* followed by *`wait()`*

7) **_____ can be used to prevent busy waiting when implementing a semaphore.**

- ☐ a. Spinlocks
- ☐ b. Waiting queues
- ☐ c. A mutex lock
- ☐ d. Allowing the `wait()` operation to succeed

8) **When using semaphores, a process invokes the `wait()` operation before accessing its critical section, followed by the `signal()` operation upon completion of its critical section. Consider reversing the order of these two operations—first calling `signal()`, then calling `wait()`.**

What would be a possible outcome of this?

- ☐ a. Starvation is possible.
- ☐ b. Several processes could be active in their critical sections at the same time.
- ☐ c. Mutual exclusion is still assured.
- ☐ d. Deadlock is possible.

VO BETRIEBSSYSTEME SS17 - #8: MEMORY MANAGEMENT

INSTRUCTIONS

This test is provided to you as part of a pilot with the goal to improve the students learning experience by making lectures more interactive. It gives you the opportunity to assess how much of the lecture you've understood and remembered.

This test will **NOT be graded**. The form will ask you to specify your gender and age for statistical purposes. The test is anonymous and giving a name is not required.

The solutions will be revealed following the collection of the completed forms.

ABOUT YOU

Gender: Age:

QUESTIONS

Please check the correct answers for each question.

1) **Absolute code can be generated for _____.**

- ☐ a. compile-time binding
- ☐ b. load-time binding
- ☐ c. execution-time binding
- ☐ d. interrupt binding

2) **Suppose a program is operating with execution-time binding and the physical address generated is 300. The relocation register is set to 100. What is the corresponding logical address?**

- ☐ a. 199
- ☐ b. 200
- ☐ c. 201
- ☐ d. 300

3) **_____ is the dynamic storage-allocation algorithm which results in the smallest leftover hole in memory.**

- ☐ a. First fit
- ☐ b. Best fit
- ☐ c. Worst fit
- ☐ d. None of the above

4) **Consider a logical address with a page size of 8 KB. How many bits must be used to represent the page offset in the logical address?**

- ☐ a. 8
- ☐ b. 10
- ☐ c. 12
- ☐ d. 13

5) **Which of the following is a benefit of allowing a program that is only partially in memory to execute?**

- ☐ a. Programs can be written to use more memory than is available in physical memory.
- ☐ b. CPU utilization and throughput is increased.
- ☐ c. Less I/O is needed to load or swap each user program into memory.
- ☐ d. All of the above.

6) **BELADY'S ANOMALY states that …**

- ☐ a. … giving more memory to a process will improve its performance.
- ☐ b. … as the number of allocated frames increases, the page-fault rate may decrease for all page replacement algorithms.
- ☐ c. … for some page replacement algorithms, the page-fault rate may decrease as the number of allocated frames increases.
- ☐ d. … for some page replacement algorithms, the page-fault rate may increase as the number of allocated frames increases.

7) **The _____ allocation algorithm allocates available memory to each process according to its size.**

- ☐ a. equal
- ☐ b. global
- ☐ c. proportional
- ☐ d. slab

8) **_____ occurs when a process spends more time paging than executing.**

- ☐ a. Thrashing
- ☐ b. Memory-mapping
- ☐ c. Demand paging
- ☐ d. Swapping

VO BETRIEBSSYSTEME SS17 - #9: MASS STORAGE

INSTRUCTIONS

This test is provided to you as part of a pilot with the goal to improve the students learning experience by making lectures more interactive. It gives you the opportunity to assess how much of the lecture you've understood and remembered.

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The solutions will be revealed following the collection of the completed forms.

ABOUT YOU

Gender: Age:

QUESTIONS

Please check the correct answers for each question.

1) **The path name `/home/people/os-student/chap10.txt` is an example of...**

- ☐ a. a relative path name
- ☐ b. an absolute path name
- ☐ c. a relative path name to the current directory of `/home`
- ☐ d. an invalid path name

2) **Transfers between memory and disk are performed…**

- ☐ a. a byte at a time
- ☐ b. a file at a time
- ☐ c. a block at a time
- ☐ d. a sector at a time

3) **A volume control block...**

- ☐ a. can contain information needed by the system to boot an operating system from that partition.
- ☐ b. is a directory structure used to organize the files.
- ☐ c. contains many of the file's details, including file permissions, ownership, size, and location of data blocks.
- ☐ d. contains information such as the number of blocks in a partition, size of the blocks, and free-block and FCB count and pointers.

4) **Which of the following allocation methods ensures that only one access is needed to get a disk block using direct access?**

- ☐ a. linked allocation
- ☐ b. indexed allocation
- ☐ c. hashed allocation
- ☐ d. contiguous allocation

5) **A RAID structure…**

- ☐ a. is primarily used to ensure higher data reliability.
- ☐ b. Is primarily used for security reasons.
- ☐ c. stands for redundant arrays of inexpensive disks.
- ☐ d. is primarily used to decrease the dependence on disk drives.

6) **What are the two components of positioning time?**

- ☐ a. seek time + rotational latency
- ☐ b. transfer time + transfer rate
- ☐ c. effective transfer rate - transfer rate
- ☐ d. cylinder positioning time + disk arm positioning time

7) **Consider a disk queue holding requests to the following cylinders in the listed order:** `116, 22, 3, 11, 75, 185, 100, 87`**. Using the SCAN scheduling algorithm, what is the order that the requests are serviced, assuming the disk head is at cylinder** `88` **and moving upward through the cylinders?**

- ☐ a. `116 – 22 – 3 – 11 – 75 – 185 – 100 – 87`
- ☐ b. `100 – 116 – 185 – 87 – 75 – 22 – 11 – 3`
- ☐ c. `87 – 75 – 100 – 116 – 185 – 22 – 11 – 3`
- ☐ d. `100 – 116 – 185 – 3 – 11 – 22 – 75 – 87`

8) **Low-level formatting...**

- ☐ a. does not usually provide an error-correcting code.
- ☐ b. is usually performed by the purchaser of the disk device.
- ☐ c. is different from physical formatting.
- ☐ d. divides a disk into sections that the disk controller can read and write.

VO BETRIEBSSYSTEME SS17 - #10: I/O SYSTEMS

INSTRUCTIONS

This test is provided to you as part of a pilot with the goal to improve the students learning experience by making lectures more interactive. It gives you the opportunity to assess how much of the lecture you've understood and remembered.

This test will **NOT be graded**. The form will ask you to specify your gender and age for statistical purposes. The test is anonymous and giving a name is not required.

The solutions will be revealed following the collection of the completed forms.

ABOUT YOU

Gender: Age:

QUESTIONS

Please check the correct answers for each question.

1) **DMA controllers…**

- ☐ a. do not utilize an additional, special purpose, processor.
- ☐ b. are a nonstandard component in PCs of today.
- ☐ c. can steal memory access cycles from the main CPU.
- ☐ d. can access main memory at the same time as the main CPU.

2) **A character-stream device…**

- ☐ a. transfers data in blocks of bytes.
- ☐ b. transfers data a byte at a time.
- ☐ c. is a device such as a disk drive.
- ☐ d. is similar to a random access device.

3) **Which of the following is true of a blocking system call?**

- ☐ a. The application continues to execute its code when the call is issued.
- ☐ b. The call returns immediately without waiting for the I/O to complete.
- ☐ c. The execution of the application is suspended when the call is issued.
- ☐ d. Blocking application code is harder to understand than nonblocking application code.

4) **A(n) _____ is a buffer that holds output for a device that cannot accept interleaved data streams.**

- ☐ a. escape
- ☐ b. block device
- ☐ c. cache
- ☐ d. spool

5) **Which of the following is a principle that can improve the efficiency of I/O?**

- ☐ a. Increase the number of context switches.
- ☐ b. Use small data transfers.
- ☐ c. Move processing primitives into hardware.
- ☐ d. Decrease concurrency using DMA controllers.

6) **An interrupt priority scheme can be used to…**

- ☐ a. …allow the most urgent work to be finished first.
- ☐ b. …make it possible for high-priority interrupts to preempt the execution of a low priority interrupt.
- ☐ c. …defer the handling of low-priority interrupt without masking off all interrupts.
- ☐ d. All of the above.

7) **The _____ register of an I/O port can be written by the host to start a command or to change the mode of a device.**

- ☐ a. status
- ☐ b. control
- ☐ c. data-in
- ☐ d. transfer

8) **A(n) _____ is a front-end processor that multiplexes the traffic from hundreds of remote terminals into one port on a large computer.**

- ☐ a. terminal concentrator
- ☐ b. network daemon
- ☐ c. I/O channel
- ☐ d. context switch coordinator

Appendix II:
User Acceptance Test -
Online Questionnaire

This appendix contains a PDF version of the interactive online questionnaire created with Google Forms.

More information on the user acceptance test and its results can be found in chapter 6: "Experimental Evaluation".

Lective Feedback

Thank you for taking the time to answer a few questions about your experience with participating in a Lective quiz.

The aim of this questionnaire is to gather feedback on the Lective prototype which is intended to be used in the lecture "Operating Systems" at the University of Vienna.

If you have any questions feel free to contact me at lective.feedback@gmail.com

* Required

1. **Age** *
   Mark only one oval.
   - ◯ 1-19
   - ◯ 20-29
   - ◯ 30+

2. **Gender** *
   Mark only one oval.
   - ◯ Female
   - ◯ Male
   - ◯ Other

3. **If you attended a lecture, would you usually bring a smartphone or other internet-capable device?** *
   Mark only one oval.
   - ◯ Yes
   - ◯ No

4. **Did you encounter any issues while using Lective?** *
   Mark only one oval.
   - ◯ Yes
   - ◯ No *Skip to question 7.*

Issues with the Lective Quiz Webapp

5. **Which of these issues was the biggest problem during your participation in the Lective quiz?** *
   Check all that apply.
   - ☐ I experienced bugs
   - ☐ The website was missing features I needed
   - ☐ The website was confusing to use
   - ☐ The website had technical difficulties that kept me from properly participating (e.g. lag, disconnect)
   - ☐ The website was visually unappealing
   - ☐ Other: _____

6. **Please give a detailed description of the issues you encountered:**

   _____

   _____

   _____

   _____

   _____

User Experience

7. **What do you like least about the Lective quiz?** *
   Mark only one oval.
   - ◯ Didn't like the questions and/or proposed answers
   - ◯ Layout/design/graphical representation of the feedback
   - ◯ Competition aspect
   - ◯ Annoying to use
   - ◯ Other: _____

8. **What do you like most about the Lective quiz?** *
   Mark only one oval.
   - ◯ Easy to use
   - ◯ Layout/design/graphical representation of the feedback
   - ◯ Interactivity vs. classical frontal teaching style
   - ◯ Competition aspect
   - ◯ Increasing learning through showing correct answers
   - ◯ Other: _____

User Satisfaction - Part I

9. **How satisfied are you with the Lective website?** *
Mark only one oval.

	1	2	3	4	5	
Very dissatisfied	◯	◯	◯	◯	◯	Very satisfied

10. **Please rate the following attributes of the Lective website:** *
Mark only one oval per row.

	Poor	Below average	Average	Good	Excellent
Quality of content (questions and answers)	◯	◯	◯	◯	◯
Ease of navigation	◯	◯	◯	◯	◯
Layout/design	◯	◯	◯	◯	◯
Feedback on quiz performance	◯	◯	◯	◯	◯
Social aspect	◯	◯	◯	◯	◯
Fun	◯	◯	◯	◯	◯

User Satisfaction - Part II

11. **Did you enjoy using Lective?** *
Mark only one oval.

- ◯ Yes
- ◯ No

12. **What did you enjoy most using Lective?**

_____

_____

_____

_____

_____

13. **How likely are you to recommend the Lective website to a friend or colleague in the future?** *
Mark only one oval.

	1	2	3	4	5	
Very unlikely	◯	◯	◯	◯	◯	Very likely

Lective as an Education Tool

14. **Did the Lective quiz successfully assess your understanding of the content?** *
Mark only one oval.

- ◯ Yes
- ◯ No

15. **Do you think a lecture with traditional frontal teaching is preferable to a lecture teaching format with short online quiz breaks?** *
Mark only one oval.

- ◯ I prefer the traditional frontal teaching lecture format
- ◯ I prefer the lecture format with short online quiz breaks

16. **Why?**

_____

_____

_____

_____

_____

Future Improvements

17. **Where do we need to improve most?** *

_____

_____

_____

_____

_____