FAKULTÄT FÜR !NFORMATIK
Faculty of Informatics

Improving Lecture Interactivity with integrated Audience Response Systems

DIPLOMARBEIT

zur Erlangung des akademischen Grades

Diplom-Ingenieur

im Rahmen des Studiums

Business Informatics

eingereicht von

Patric Prasch BSc
Matrikelnummer 1025333

an der Fakultät für Informatik
der Technischen Universität Wien

Betreuung: Ao. Univ.Prof. Dr. Stefan Biffl
Mitwirkung: Dr. Dietmar Winkler

Wien, 20. April 2016

Unterschrift Verfasser

Unterschrift Betreuer

FAKULTÄT FÜR !NFORMATIK
Faculty of Informatics

Improving Lecture Interactivity with integrated Audience Response Systems

MASTER THESIS

submitted in partial fulfillment of the requirements for the degree of

Diplom-Ingenieur

in

Business Informatics

by

Patric Prasch BSc
Registration Number 1025333

to the Faculty of Informatics
at the Vienna University of Technology

Advisor: Ao. Univ.Prof. Dr. Stefan Biffl
Assistance: Dr. Dietmar Winkler

Vienna, 20th. April, 2016

Signature Author

Signature Advisor

Erklärung zur Verfassung der Arbeit

Patric Prasch BSc

Aderklaaer Straße 29/3/13, 1210 Wien

Hiermit erkläre ich, dass ich diese Arbeit selbständig verfasst habe, dass ich die verwendeten Quellen und Hilfsmittel vollständig angegeben habe und dass ich die Stellen der Arbeit – einschließlich Tabellen, Karten und Abbildungen –, die anderen Werken oder dem Internet im Wortlaut oder dem Sinn nach entnommen sind, auf jeden Fall unter Angabe der Quelle als Entlehnung kenntlich gemacht habe.

Wien, 20. April 2016

Unterschrift Verfasser

Acknowledgements

I am using this opportunity to thank all people who accompanied me on the ride of writing this thesis.

I want to thank Stefan Biffl, for his supervision of this thesis and his enthusiasm while testing the first implemented prototypes of the integrated Audience Response System in his lectures.

I want to thank Dietmar Winkler, for being my advisor while I wrote this thesis and the time he spend on long Skype meetings where he provided valuable and comprehensive feedback.

I want to thank my girlfriend Selina Prirsch, for her attempts to motivate me to keep writing this thesis and her patience with me when I was annoyed while writing this thesis.

I want to thank the Presentr-Team (Florian Hotarek, Philipp Klein, Clemens Proyer and Mattias Haberbusch) for their dedication to the Presentr project.

I want to thank Elisabeth Mayrhofer for proofreading this thesis and improving my English writing skills.

I want to thank the Teaching Support Center of the Vienna University of Technology, in particular Gottfried Csanyi, for enable me to send the lecturers survey to all lecturers at the Vienna University of Technology.

Abstract

Audience Response Systems (ARS) help to engage students during lectures in large education environments. This thesis investigates a specific type of Audience Response Systems, the integrated Audience Response Systems (iARS). Integrated Audience Response Systems combine the presentation slides of a lecturer with the question-driven interactive tasks of classic ARS. This approach delivers new possibilities for lecturers and their students, for example the automatic start of interactive tasks at specific points in a presentation or the combined export of the presentation slides with the results of the interactive tasks. The objectives of this thesis are the analyzation of iARS requirements and system designs which fulfils them, evaluation methods which are suitable for iARS and the investigation of the demand for an iARS in context of university education. To evaluate the proposed requirements and system designs two prototypes were implemented within an iterative software development process. Different evaluation methods were used to find suitable approaches and a lecturer survey addressing all lecturers at the Vienna University of Technology was conducted to investigate the demand for integrated Audience Response Systems in university education. A case study which was conducted to evaluate the requirements and the system design of the second prototype was deployed within 5 real world lecture courses where the second prototype was evaluated during 14 lecture units. The enrolled students' survey, with 247 participants, showed that 87% of the students found the deployment of the iARS prototype during the lecture useful and 91% of the students would use the tool again in other lectures. The results of the conducted survey for the lecturers, where 102 individual responses were collected, showed a high demand for integrated Audience Response Systems since 82% of the lecturers would consider using an iARS in their future lectures.

Kurzfassung

Audience Response Systeme (ARS) helfen dabei, die Interaktivität zwischen Vortragenden und Studenten in großen Lehrumgebungen zu erhöhen. In dieser Arbeit wird eine bestimmte Klasse von Audience Response Systemen untersucht, die integrierten Audience Response Systeme (iARS). Integrierte Audience Response Systeme kombinieren das Vortragen von Präsentationsfolien mit dem Einsatz von interaktiven Aufgaben, wie aus klassischen ARS bekannt. Diese Eigenschaft bietet neue Möglichkeiten für Vortragende und deren Studenten. Zum Beispiel können interaktive Aufgaben an einem bestimmten Punkt in der Präsentation automatisch gestartet werden oder es kann ein kombinierter Export der Präsentationsfolien mit den Ergebnissen der interaktiven Aufgaben erfolgen. Die Ziele dieser Arbeit sind die Analyse der Anforderungen, die an integrierte Audience Response Systeme gestellt werden, die Entwicklung von System Designs, welche die analysierten Anforderungen erfüllen, die Untersuchung von Methoden, die zur Evaluierung von iARS dienen und die Erhebung der Nachfrage nach iARS im universitären Kontext. Zur Evaluierung der ermittelten Anforderungen und des entwickelten System Designs wurden zwei Prototypen mittels eines iterativen Software-Entwicklungsprozesses implementiert. Verschiedene Evaluierungsmethoden wurden eingesetzt um die Prototypen zu bewerten. Um die Nachfrage nach integrierten Audience Response Systemen zu erheben, wurde eine Befragung der Vortragenden durchgeführt; alle Lehrenden der Technischen Universität Wien wurden eingeladen, an einer Online-Umfrage teilzunehmen. Zur Evaluierung der Anforderungen und des System Designs wurde eine Fallstudie des zweiten Prototyps durchgeführt. Dabei wurde der Prototyp in 5 verschiedenen realen Lehrveranstaltungen eingesetzt und konnte dabei in insgesamt 14 Vorlesungseinheiten die Interaktivität zwischen Vortragenden und Studenten erweitern. An der im Zuge der Fallstudie durchgeführten Befragung der Studenten nahmen 247 Personen teil. Die Evaluierung zeigte, dass 87% der Studenten den Einsatz des iARS Prototyps während der Vorlesung sinnvoll fanden und 91% der Studenten ihn auch in anderen Lehrveranstaltungen wieder verwenden würden. Die Ergebnisse der durchgeführten Befragung der Vortragenden, an welcher sich 102 Personen beteiligten, zeigte, dass 82% der Lehrenden sich vorstellen können, ein solches System in ihren zukünftigen Vorlesungen einzusetzen und somit eine hohe Nachfrage nach integrierten Audience Response Systemen im universitärem Kontext vorhanden ist.

Terms and Abbreviations

API	Application Programming Interface
ARS	Audience Response System
BYOD	Bring Your Own Device
CRS	Classroom Response System synonym for **ARS**
CSV	Comma-Separated Values
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
I/O	Input / Output
iARS	integrated Audience Response System
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
JSON	JavaScript Object Notation
MVC	Model-View-Controller
PDF	Portable Document Format
PDCA	Plan-Do-Check-Act
REST	REpresentational State Transfer
SQL	Structured Query Language
SRS	Student Response System synonym for **ARS**
SSO	Single-Sign-On
URL	Uniform Resource Locator
WLAN	Wireless Local Area Network
XML	eXtensible Markup Language

Table of Contents

1. Introduction

"Audience response systems (ARS) or clickers, as they are commonly called, offer a management tool for engaging students in the large classroom." [Caldwell, 2007, p. 9]

1.1. Motivation

Modern support for class-room teaching has augmented analog methods with a wide variety of digital technologies. New forms of presentation types have been constructed with the support of Audience Response Systems (ARS) and research in Educational Technology leading to new possibilities for transferring knowledge.

According to the literature review of Kay and LeSage, Audience Response Systems can provide the following benefits to education environments: Students are more focused in class, students participate with peers more in class to solve problems, students are more engaged in class and students go more to class. Additionally with ARS the concept of contingent teaching, where the lecturers modify their instructions based on the feedback from the students, can be deployed in lectures. [Kay & LeSage, 2009, p. 822]

This thesis investigates a specific type of Audience Response Systems, the integrated Audience Response Systems (iARS). Integrated Audience Response Systems combine the presentation slides of a lecturer with the question-driven interactive tasks of classic ARS. This approach delivers new possibilities for lecturers and their students, however introduces new risks and complexity.

1.2. Problem statement

As the concept of integrated Audience Response Systems is a new approach in the field of education technology, the requirements of such systems should be investigated. In addition the system design of a tool following the class of integrated Audience Response Systems and fulfilling the emerging requirements should be developed.

The evaluation of integrated Audience Response Systems is another topic that should be investigated. Because the evaluation of a developed system is an important part in scientific research, the evaluation possibilities emerging for integrated Audience Response Systems should be analyzed.

To assess the practical value of this research, the demand for an integrated Audience Response System in university education should be evaluated. Additionally the current lecture processes of the lecturers regarding their preparation and presentation phases are a topic of interest for this thesis.

All topics should be discussed and evaluated in the context of large scale education environments, as they are the main deployment field of Audience Response Systems.

The research is restricted on web-based systems; to remain compatible with the huge amount of heterogeneous devices used today by students and lecturers. Recent studies of undergraduate students at American colleges and universities showed that 98% of the students own at least one internet-capable device. [Dahlstrom, Brooks, Grajek, & Reeves, 2015, p. 14]

1.3. Aim of the work

Based on the problem definition, the following research questions have been defined as prime focus of this thesis. A detailed elaboration of the research questions can be found in chapter 3.

RQ1 **iARS requirements and system design.** Which requirements emerge for web-based iARS and which system design fulfils them in a large scale education environment?

RQ2 **iARS prototype evaluation.** Which methods are suitable to evaluate web-based iARS prototypes in a large scale education environment?

RQ3 **iARS lecturers survey.** Which insights can be gained from currently established lecture processes and is there a demand for an iARS in university education?

1.4. Methodological approach

The following methodological approach is used to answer the research question.

1. **Literature research.** The requirements of the literature are summarized and categorized.
2. **Expert discussion.** Additional requirements emerge from an expert discussion and get combined with the requirements from literature.
3. **Prototype development.** The integrated Audience Response System prototype is implemented.
4. **Pilot test.** The first integrated Audience Response System prototype is evaluated during a pilot test.
5. **Improved requirements.** After the first prototype was evaluated during a pilot test, the emerged feedback of the test is transformed into new requirements.
6. **Improved prototype development.** The improved integrated Audience Response System prototype is implemented.
7. **Case study.** After the improved prototype is implemented, it is deployed in different lecture courses and multiple lecture units.
8. **Lecturers' survey.** A survey for the lecturers is conducted to gain insights into currently established lecture processes.

The methodology and approach is described in detail in chapter 4 and is visualized in Figure 3 in the same chapter.

1.5. Structure of the work

In chapter 2 the Audience Response System literature research of is described. Chapter 3 describes the research questions in detail. Chapter 4 delivers a detailed description of the applied research approach. Chapter 5 covers the topics of the prototype development; chapter 6 covers the topics of the improved prototype development as shown in figure 3. Chapter 7 describes the design and the results of the lecturer survey. Chapter 8 discusses and answers the proposed research questions. The thesis concludes with a summary and gives recommendations for future work in chapter 9.

2. Related Work

In this chapter the current literature, regarding the topics of this thesis, is reviewed. At first the requirements of Audience Response Systems are examined. Secondly the different interactive task types of ARS are studied. Thirdly the evaluation of ARS tools is investigated. The chapter concludes with a review about literature discussing aspects of integrated Audience Response Systems.

The following scientific knowledge libraries were used to perform the literature research:

- Elsevier[1]
- Google Scholar[2]
- IEEE Xplore[3]
- Springer[4]
- TU-Wien UB CatalogPlus[5]

To parameterize the searches in the respective scientific knowledgebase the following keywords have been used:

audience response system, integrated audience response system, classroom response system, student response system, personal response system, interactive response, integrated system, combined system, e-learning, requirements, benefits, limitations, tool, clicker, flipped classroom, mobile learning, educational technology, computer supported collaborative learning, presentation support, presentation system

The searches in the knowledge libraries were limited to literature published after 01.01.2000.

[1] **Elsevier.** https://www.elsevier.com
[2] **Google Scholar.** https://scholar.google.com
[3] **IEEE Xplore.** http://ieeexplore.ieee.org
[4] **Springer.** http://www.springer.com
[5] **TU-Wien UB CatalogPlus.** http://catalogplus.tuwien.ac.at

2.1. Audience Response System requirements

Before developing a new integrated Audience Response System, already developed tools and proposed requirements should be analyzed. To benefit from lessons learned/best practices from other researchers, the given recommendations, proposed architectures, challenges during the development process and restrictions of other tools will be investigated. The following questions will be elaborated in this chapter:

- What requirements were proposed in literature for (web-based) Audience Response Systems?
- What system architectures were mentioned for ARS?
- What recommendations were given when implementing an ARS?
- What challenges had been faced in the development of an ARS?
- Which restrictions or limits have been found in the deployment of ARS?

In "AuResS: The Audience Response System" [Jagar, Petrovic, & Pale, 2012] a web based audience response system had been developed. The system was restricted to multiple choice responses with 2-5 answer options; this upper limit was selected to ensure simple questions for the audience and due to device screen restrictions. Under these assumptions the authors defined the requirements cited in table 1. Especially the abilities for the lecturer to start and stop the voting process, to show results only after the voting process to prevent students from follow other votes and to access the voting page quickly and easily are interesting.

Requirements
The lecturer has to be able to start and stop votes accepting. He also has to be able to choose whether to show results during the voting or only when the voting has finished, in order to prevent students from adapting their votes based on other students' votes.
During the voting time, students might change their mind and vote again. The lecturer therefore has to be able to choose whether to display only the first vote or the last, final vote of each student.
The system will maintain student's anonymity, but will identify individual phones using browser cookies in order to recognize when two or more votes come from the same phone. As interim solution, in situations where some students might not have their own smartphones, the lecturer might allow votes from the same phone to be registered as separate votes.
The system has to enable the lecturer to pose multiple successive questions during the same lecture and to separately record their votes.
Another important request on the system is to enable downloading or e-mailing of all the acquired data for later statistical analysis. This would enable the lecturer to have a detailed insight into the students' misconceptions or general audience behavior.
The system has to enable the lecturer to use it anonymously. However, if the lecturer is foreseeing his possible need to reenter the room, he will have an option to give his e-mail address when creating the room for the first time.
The system has to enable the lecture audience a quick and easy access to the voting page. Voting page should have a short and simple to remember URL and the room access could be even further facilitated by a direct QR code.

Table 1: AuResS requirements cited from [Jagar, Petrovic, & Pale, 2012, p. 172]

In “Survnvote: A Free Web Based Audience Response System to Support Interactivity in the Classroom” [Mantoro, Ayu, Habul, & Khasanah, 2010] extension to the existing publicly available ARS tool Votapedia[6] had been developed. The ARS had a web-based and a SMS interface, allowing the students to answer via a browser or a non-browser enabled mobile. An excerpt of the requirements defined for the web-client part of the developed system is listed in table 2. Interesting are the different options for closing an active survey either by stopping through the lecturer or by time setting, the ability to continue a stopped survey and the re-run of the same survey several times.

Requirements
The survey will be active in front of audiences, showing the questionnaire or quiz including 3 modes of participation, i.e. through mobile phones, SMS and web.
The survey can be closed in two ways: stopped by survey creator or by time setting.
During the survey, the survey creator can add more time on the fly.
After the survey is stopped, the creator can continue the survey.
The creator can re-run the same survey several times for different audiences without any need to worry that the previous survey will be missing. He/she can compare the results at the end of the survey.
The creator can decide, whether the user can only see the results when the survey has finished or after he/she voted.
Answer data and whole data of the final result can be exported to Excel and PowerPoint.

Table 2: Survnvote requirements cited from [Mantoro, Ayu, Habul, & Khasanah, 2010]

In “Classroom Response Systems in Higher Education: Meeting User Needs With NetClick” [Abramson, Pietroszek, Chinaei, Lank, & Terry, 2013] a web-based ARS got developed and evaluated. Despite the paper focus on the newly introduced interactive task region of interest or also called heat map, they developed an integrated Audience Response System where controlling the presentation slides on the one hand and the interactive tasks on the other hand were merged into one system. The requirements of the system were not explicitly stated in the paper; therefore some functions of the system were extracted from the paper and stated in table 3. Because of the integrated aspect of this tool the requirements regarding the presentation slides are of great interest. The requirements, defining the control of the presentation slides and the restriction for the student to not advance past the current slide of the lecturer, are of high value.

Requirements
Once connected to a presentation, each student sees the currently displayed slide on their device.
The Professor may advance to the next slide by using either the arrow key or the space bar.
Students however cannot advance forward past the currently displayed slide.
The 6-letter code and the control buttons for the Professor are displayed on a toolbar that, by default, is visible for the first three slides of their presentation.
Following a NetClick interaction, the Professor may either hide the interaction overlay by clicking the ‘display interaction’ toggle and return to the current slide, or advance to the next slide.

Table 3: NetClick requirements cited from [Abramson, Pietroszek, Chinaei, Lank, & Terry, 2013]

[6] **Votapedia.** https://en.wikiversity.org/wiki/VotApedia

In “Developing a Web-Based Question-Driven Audience Response System Supporting BYOD” [Haintz, Pichler, & Ebner, 2014] the web-based ARS “RealFeedback” had been developed. Existing web-based ARS have been compared; the found features were taken as base for a new ARS. Table 4 lists the requirements, which were classified as most relevant, for the new ARS. The focus in the development of the new system was to keep it simple and lean, as the comparison of existing publicly available web-based ARS shows over-engineered and overly complicated solutions.

Requirements
Cross-platform capabilities
Prioritize user experience against feature richness
Web-based user interface
Group questions
Anonymous voting
Multiple choice questions
Show the number and percent of votes for an answer
Visualize the result as bar chart

Table 4: Relevant requirements cited from [Haintz, Pichler, & Ebner, 2014, p. 8]

Beside the requirements, also the architecture and technology stack of the developed ARS were presented in the paper “Developing a Web-Based Question-Driven Audience Response System Supporting BYOD” [Haintz, Pichler, & Ebner, 2014]. The client-server communication had been visualized in a diagram. Figure 1 shows the diagram as it was illustrated in the reference.

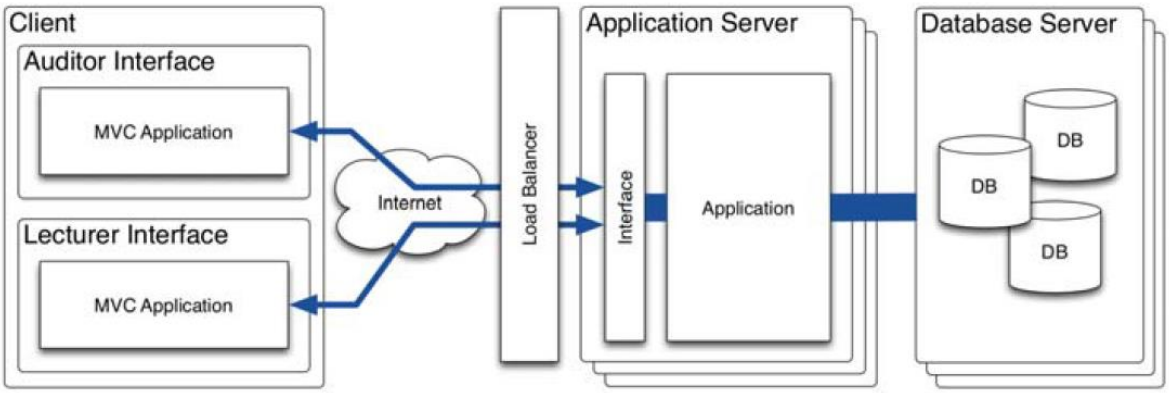


Figure 1: Architecture of RealFeedback system cited from [Haintz, Pichler, & Ebner, 2014, p. 10]

Preceding the development of the web-based ARS in “Developing a Web-Based Question-Driven Audience Response System Supporting BYOD” [Haintz, Pichler, & Ebner, 2014], a comparison between the features of existing and publicly available ARS, was conducted. 12 tools were analyzed and their features were categorized. The authors mainly focused on functions and features of the interactive task type survey. The following attributes were analyzed: respond type (e.g. via SMS, website or mobile app), general features (e.g. sort, copy questions, anonymous voting), available question types, provided question features (e.g. view percentage and total number of votes, support math equations), the visualization types of the results and options for reporting and statistics.

In the category “general features”, 3 out of the 12 investigated tools had the ability to copy predefined questions, one tool supported the automatic start and stop of questions, 6 tools allow to clear the data of questions without losing previously collected answers and 8 tools support the anonymous voting of students.

The category “question features” analyzes functions related to the execution of interactive tasks. 3 out of 12 tools support to hide the votes from the students until the question has been finished and the voting was closed. 10 systems display the total number of votes and the related percentages. 5 tools enable the lecturer to mark answer options as correct; therefore support the interactive task type quiz.

In the category “visualization”, all analyzed tools display their results as bar charts, 2 out of 12 tools can additionally visualize the results as pie chart and 5 tools visualize the results on the clients of the students.

In the category “reporting and statistics” the output and export capabilities of the tools were analyzed. 4 out of the 12 analyzed tools support downloadable reports, 3 of them output CSV files, one generates xls[7] files. 5 tools let the lecturer evaluate and download results from previous sessions.

During the evaluation of the ARS developed in “Developing a Web-Based Question-Driven Audience Response System Supporting BYOD” [Haintz, Pichler, & Ebner, 2014], four lecturers that used the system were interviewed and asked if they are lack in some features or functions. Table 5 shows the mentioned missing features and how many interview partners mentioned them.

Missing features	**No. of mentions**
A visualization of how many students have already voted for the question is missing	4
Defining the correct answer is missing	3
Comparison of the results over different sessions is missing	3
A mobile application is missing	1
A function for taking notes for a question is missing	1
Visualizing how fast the students responded to a question is missing	1

Table 5: Missing features cited from [Haintz, Pichler, & Ebner, 2014, p. 53]

The evaluation study in “CREATING ACTIVE LEARNING IN A LARGE INTRODUCTORY STATISTICS CLASS USING CLICKER TECHNOLOGY“ [Mateo, 2010], where the clicker-based ARS i>clicker[8] was used one semester with 290 students, lists some issues that were experienced during the pilot project. Although the study indicates a positive impact on student attendance and an increased student engagement in large class lectures, some challenges were encountered by lecturers and students. Table 6 lists some of these challenges that were summarized from “CREATING ACTIVE LEARNING IN A LARGE INTRODUCTORY STATISTICS CLASS USING CLICKER TECHNOLOGY” [Mateo, 2010]. The challenges stated provide helpful input for conducting the lecturer survey; the lecturers can be asked

[7] **Excel xls.** https://msdn.microsoft.com/de-de/office/bb906068.aspx
[8] **i>clicker.** https://www1.iclicker.com

how much time they will spend on preparing an interactive task before a lecture or spend on conducting an interactive task during their lectures.

Challenges
Integration of i>clickers with course material was time consuming.
Integration of i>clickers with course material exceeded estimates of required time.
Individual instances of i>clicker use took 1-2 minutes, perceived by educators as too long.
Management of i>clickers involved dealing with lost and defective hardware units.
Students expected educators to resolve issues in i>clicker management.

Table 6: Stated challenges cited from [Mateo, 2010, p. 5]

In the literature review of Kay and LeSage "Examining the benefits and challenges of using audience response systems: A review of the literature" [Kay & LeSage, 2009] in chapter 3.2 "Challenges to using ARSs" the authors describe challenges, which are emerging when using an Audience Response System. Table 7 lists the challenges that were found during the literature review. The challenges were categorized in "Technology-based challenges", "Teacher-based challenges" and "Student-based challenges". While some of these challenges are not directly related to the development phase of the iARS they deliver input for the pilot test and case study regarding which topics should be watch out for.

Challenges	Description
Technology-based challenges	
Bringing remotes	Students forgot or lost remotes and could not participate in class
ARS did not work	Remote devices did not function properly
Teacher-based challenges	
Responding to student feedback	Less experienced teachers cannot adjust to student feedback
Coverage	Cover less course content if ARS is used
Developing questions	Time consuming to create ARS questions
Student-based challenges	
New method	Students find it difficult to shift to a new way of learning
Discussion	Discussion leads to confusion or wasting time
Effort	Too much effort is required by students when using ARSs
Summative assessment	Using ARS for tests may not be popular with students
Attendance for grades	Students do not like ARSs used for monitoring attendance
Identifying students	Students want to remain anonymous
Negative feedback	Students feel bad when receiving negative feedback

Table 7: ARS challenges cited from [Kay & LeSage, 2009, p. 824]

In summary there is a whole body of requirements stated in the literature. While not all of them can be taken over to the development of a web-based ARS, either because they are not relevant for a web-based system, are outdated or are conflicting with other requirements, they form a strong baseline for further investigations and improvements. Chosen requirements will be used as initial requirement set for the web-based integrated Audience Response System prototype described in chapter 5.

2.2. Audience Response System interactive task types

After the requirements of an Audience Response System got investigated the implemented interactive task types get an additional focus. Choosing the right interactive task type is very significant for an Audience Response System. The interactive task type decides how the lecturers and students can interact with each other in context of an Audience Response System. Mischosen interactive task types can lead to tasks that are not applicable in university context and cab lower the unwillingness to use the system by the lecturers and students. The following questions will be elaborated in this chapter:

- What different interactive task types of an ARS have been proposed or were implemented?
- What interactive task types can be found in public educational/commercial ARS systems?
- What interactive task types are implemented often or rarely?

After reviewing the literature about implemented ARS tools, an overview of the implemented interactive task types is given. Each identified interactive task type is described in detail. Summary table 8 shows which interactive task types were found in which research contribution, a sum of how often the task type was found in the literature and the relative occurrence in the eight investigated requirement references.

Description of the interactive task types

Single-/Multiple-Choice Survey. The lecturer defines a question and possible answer options. The students choose one, if the survey is single-choice, or more, if the survey is multiple-choice, of these answer options. The result is the sum/percentage how often each option has been chosen.

Open Question. The lecturer defines a question. The students can answer them with freely typed text. The result contains each answer from the students.

Quiz. The lecturer defines a question, possible answer options and the correct answer set. The students choose one or more of the answer options. The result is the percentage between correct and incorrect answers.

Sort / Rank. The lecturer defines a question and answer items. The students rank the predefined items in their own order. The result is how many students have each item on which rank or an average ranking based on the student's choices.

Region of Interest / Heat Map. The lecturer prepares a specific presentation slide. During the lecture the students click on a position within this slide. The result is a heat map where the clicks of the students get visualized. Possible usages could be fault finding in a model or clicking on part of formulas that were not understood.

True / False. A derivate of a single-choice survey with only 2 answer options (e.g. yes/no, true/false).

Draw / Sketch. The lecturer defines a question. The students respond to the question with a drawing. The result contains each drawing from the students.

Scale / Numeric. The lecturer defines a question and a scale, like 1 to 10. The students choose a number in the scale. The result is the average of the chosen numbers.

Interactive task type	Found in literature	Occurrences in literature	Relative occurrences
Single-/Multiple-Choice Survey	[11],[12],[14],[15],[16],[17]	6	75%
Quiz	[12],[13],[16]	3	38%
Draw / Sketch	[10],[11]	2	25%
Open Question	[11],[17]	2	25%
Sort / Rank	[11],[12]	2	25%
Region of Interest / Heat Map	[11],[18]	2	25%
True / False	[11]	1	13%
Scale / Numeric	[17]	1	13%

Table 8: Interactive task types found in literature

In "Developing a Web-Based Question-Driven Audience Response System Supporting BYOD" [Haintz, Pichler, & Ebner, 2014] twelve publicly available web-based ARS were evaluated and compared against each other. Beside other characteristics the available questions types were listed. Table 9 shows the found occurrences of the interactive task types, within the twelve evaluated ARS at their state of April 2013. The interactive task types "scale / numeric" and "draw / sketch" were not listed in the reference.

Interactive task type	Occurrences in public tools	Relative occurrences
Single-/Multiple-Choice Survey	12	100%
Open Question	7	58%
Quiz	5	42%
Sort / Rank	2	17%
True / False	2	17%
Region of Interest / Heat Map	1	8%

Table 9: Interactive task types in public tools cited from [Haintz, Pichler, & Ebner, 2014, p. 44]

After reviewing the literature about implemented ARS tools, an overview of the implemented question types is given. Table 10 shows how often an interactive task type was found in the literature referenced from table 8, in the publicly available tools from table 9, in total and in relative occurrence to the 20 investigated tools.

Interactive task type	Total from table 8	Total from table 9	Sum of totals	Sum in %
Single-/Multiple-Choice Survey	6	12	18	90%
Open Question	2	7	9	45%
Quiz	3	5	8	40%
Sort / Rank	2	2	4	20%
Region of Interest / Heat Map	2	1	3	15%
True / False	1	2	3	15%
Draw / Sketch	2	-	2	10%
Scale / Numeric	1	-	1	5%

Table 10: Summary of interactive task types

The top ranked interactive task type is the single- and multiple choice surveys, it was available in most of the investigated ARS tool from the literature and in all analyzed publicly available tools. With only half of the occurrences the second place goes to the interactive task type open question found in some developed tools from literature and in more than the half of the investigated public ARS tools. With only one occurrence behind lies the interactive task type quiz, which was found in three tools from the literature and in five tools from publicly available tools. Other interactive task types were only found in four or less of the overall investigated 18 tools.

2.3. Evaluation of Audience Response Systems

After analyzing the requirements and interactive task types of Audience Response Systems, the evaluation of ARS tools get investigated. This provides some insights on how the developed tools were evaluated and which methods delivered good evaluation results. Additionally it will enrich the design of the pilot test, the case study and the survey for the lecturers. The following questions will be elaborated in this chapter:

- Which different ARS tools have been evaluated?
- Which of them were evaluated in university context?
- What aspects of the ARS got evaluated?
- What methods were used to evaluate ARS?
- What were the results of the ARS tool evaluations?

In "Design, Implementation and Evaluation of a Tablet-based Student Response System for an Engineering Classroom" [McLoone, O'Keeffe, & Villing, 2013] a tablet based classroom response system was developed. The developed tablet app for the students allow them to make a sketch/draw response to a question from the lecturer. The app got evaluated by surveying the students using paper questionnaires. The sample size was one classroom of students in Electronic Engineering consisting of 13 students. The questionnaire used a 5-point-Likert scale to collect answers from the students.

The results of the evaluation were highly positive, probably due to the relative small sample size. The students answered with a mean of 4.6 and a standard deviation of 0.5 to the statement "The flexibility of providing a sketch is really useful". The response to the statement of "The use of the response system makes my learning more enjoyable" was 4.8 on an average with a standard deviation of 0.6. The willingness to reuse the Audience Response System again was also very high with a mean of 4.8 and a standard deviation of 0.4.

Overall finding was that "…students found the idea of responding with sketches useful, flexible and a good means of giving feedback and interacting in class." They also asked the students for improvements resulting in the need of more draw colors, undo function and the use of a stylus.

In "A study on the influence of rich versus traditional classroom response system (CRS) questions on concept retention" [Bakrania, 2012] a self-developed mobile based classroom response system was investigated. The system consists of an iPhone/iPad app, for interacting with the students and a web-server, for collecting and analyzing the results. The system got evaluated by surveying 28 students via a questionnaire deployed by the same iPhone/iPad[9] app.

The result of the question "How useful was the response experience" which was asked through the questionnaire was mainly positive. 3% of the students chose the statement "Hindered learning", 11%

[9] **iPhone/iPad.** https://developer.apple.com

chose “Not useful”, 65% chose “Somewhat useful” and 21% of the students set their mark on the statement “Greatly helpful”.

The conclusion was that “The students especially appreciate the highly visual aspects of interactions offered”.

In “A Pilot Study of QuizIt: the New Android Classroom Response System” [Karakostas, Adam, Kioutsiouki, & Demetriadis, 2014] a self-developed, smartphone based classroom response system got evaluated. An android[10] app for the lecturers and students was developed, giving the lecturer the possibility to issue multiple choice questions to the students. The system was used by 23 informatics students during a lecture; afterwards they got surveyed via an online questionnaire. The questionnaire asked the students 14 questions about the usability of the app and the overall experiences and provided them a 5-point-Likert scale for their responses.

The result of the evaluation, where all 23 students participated, was positive. The students answered with a mean of 4.17 and a standard deviation of 0.64 to the statement “The experience with the application was positive”. The response to the statement of “It was easy to use the application” was 4.83 on an average with a standard deviation of 0.38. The willingness to reuse the Audience Response System again in other courses was also very high with a mean of 4.52 and a standard deviation of 0.58.

In “CREATING ACTIVE LEARNING IN A LARGE INTRODUCTORY STATISTICS CLASS USING CLICKER TECHNOLOGY” [Mateo, 2010] the clicker-based ARS tool i>clicker[11] was used in two courses of Statistical Analysis during one whole semester. A study was conducted to examine and evaluate students’ perceptions and attitudes on the ARS system. 290 students participated in the conducted survey, which was enrolled in the last week of the courses. The survey offered the students a 5-point-Likert scale for their responses. An excerpt of the results, which were derived for each of the two courses separately, are listed in table 11, results marked with a * are significantly different between the two courses. The results indicate that the students reacted positively to the use of the ARS tool in aspects of perception and attitude. Only in two of the six questions a significant difference in the students answer distribution between the two courses has been found.

The conclusion of the study was that “Although, the i>clicker technology was just implemented for the first time, it gives a positive impact on student attendance, and most of all, it increased the students’ engagement in the large class lecture environment”.

[10] **Android.** http://developer.android.com
[11] **i>clicker.** https://www1.iclicker.com

Question	Average rating (Course 1 / Course 2)	Std. dev. (Course 1 / Course 2)
Clickers led me to become engage [sic] in class.	4.48 / 4.27	1.04/1.12
Clickers increased the frequency of participation in the course.	4.10 / 3.92*	0.74/0.93*
Using clickers helped me to pay attention in class.	4.28/4.13	0.99/1.07
Clickers helped me get instant feedback on what I knew and didn't know.	4.31/4.37	0.76/1.11
Clickers have been beneficial to my learning.	3.88/3.91	0.68/0.76
Using the clickers helped me get a better mark in homework and tests.	3.32/4.08*	0.93/0.98*

Table 11: Results from i>clicker evaluation cited from [Mateo, 2010, p. 4]

In "Concurrent Use of an Audience Response System at a Multi-Campus College of Pharmacy" [Clauson, Alkhateeb, & Singh-Franco, 2012] a clicker based ARS was evaluated. The study, which surveyed students of a course in pharmacy, was conducted at three different education institutions. The courses were broadcasted synchronously via interactive video, allowing the students to ask questions from each location, to two sides in Florida and one in Puerto Rico. The students were surveyed after the course lecture, where the ARS was deployed lastly, via an online questionnaire. A total of 177 students participated in the survey out of the 208 students that were enrolled in the course. The questionnaire consisted of 21 survey items and provided a 5-point-Likert scale for the students' responses. An excerpt of the results of the survey is listed in table 12.

Survey item	Mean	Std. dev.
The use of response cards in this course encouraged me to participate in class	4.4	0.8
The use of response cards in this course was distracting	2.2	1.0
Because of the response cards, I participated more in this class than I normally do	4.2	1.0
I valued that the response cards allowed people to respond anonymously	4.4	0.7
The use of response cards helped make some topics clearer	3.8	1.0
Overall, I think having the response cards made the class better	4.1	0.8
The use of response cards made it easier to participate when the professor was lecturing from a different site	4.1	0.8
I hope more courses will adopt the use of response cards	3.7	1.0

Table 12: Student survey results cited from [Clauson, Alkhateeb, & Singh-Franco, 2012, pp. 3-4]

The conclusion was that the *"Implementation of an ARS was associated with positive student perceptions of engagement and may improve feelings of connectedness among students at schools with multiple sites."* [Clauson, Alkhateeb, & Singh-Franco, 2012, p. 6].

In "Classroom communication on mobile phones – first experiences with web-based 'clicker' system" [Lam, Wong, Mohan, Xu, & Lam, 2011] a hybrid ARS, allowing answers via website or dedicated clicker, got evaluated in two different universities. The ARS was used in two different courses on each university and got applied three and four times during the semester. The students were surveyed by paper questionnaires at the end of the courses. The results were presented separately for both courses. In case 1, 36 of the 61 students responded to the survey. In case 2, the students responded to the ARS questions in groups, therefore the 20 group leaders were surveyed, 16 of them answered the survey. The questionnaire consisted of 18 survey items and provided a 5-point-Likert scale for the students' responses. Additionally the results of case 2 were divided in whether the students used the distributed clicker or the webpage for responding. A segment of the results of the survey is listed in table 13.

Question	**Case 1**	**Case 2 / Clicker**	**Case 2 / Webpage**
Participation with clickers increased my interaction with the instructor.	3.89	4	4.25
Using clickers can keep the students engaged.	3.64	3.71	4
Using clickers during lectures helps me clarify whether I understand course concepts.	3.69	4	4.25
I believed I learned more in this class due to the use of the clickers.	3.00	3.14	3.25
I enjoyed participation with clickers.	3.50	3.57	3.75
Clickers keep me interested in the lecture.	3.39	3.71	4
I would recommend using clickers again in this course.	3.53	3.86	4.25
I would prefer that my others courses also use clickers.	3.43	3.57	3.75

Table 13: Student survey results cited from [Lam, Wong, Mohan, Xu, & Lam, 2011, pp. 769-773]

In "Promoting student-centered active learning in lectures with a personal response system" [Gauci, Dantas, Williams, & Kemm, 2009] a clicker based ARS got evaluated, after using it in an undergraduate physiology course with 175 students consisting of 33 lecture units during a whole semester. The student participation rate for using the clicker was 85% ± standard error of 0.8. The students got surveyed at the end of the semester via a questionnaire consisted of a five-point Likert

scale and open-ended questions. 147 students answered the questionnaire. Table 14 lists some of the survey results.

Question	n	Mean	Standard Error
I was more engaged/interested in lectures where voting occurred.	145	4.0	0.06
Voting in the lectures improved my understanding of physiology.	142	4.0	0.06
The PRS (personal response system) contributed effectively to my overall learning in this subject.	125	3.9	0.07
Voting encouraged me to attend more lectures than I normally would have.	144	2.6	0.09
I would have preferred if the voting (or some of the voting) was an assessable component of this subject.	145	2.4	0.10

Table 14: Student survey results cited from [Gauci, Dantas, Williams, & Kemm, 2009, p. 65]

The answers to the open-ended questions got analyzed and the most given answers were listed. 50% of the students stated that they sometimes forgot to bring their clicker to the lecture. Asked for the impact they use of the clicker had on them, 21% of the students answered that it made them think or actively learn, 13% stated that it reinforced or consolidated the material and 11% responded that it assisted with understanding the material. Asked what they like at least about the clicker deployment, 29% of the students stated that it was time consuming and 12% answered that there were technical problems during the lecture. As conclusion the following statement were denoted:

Significant improvement was evident in both mid- and end-semester exam results compared with student cohorts from preceding years, although this could also be influenced by many other factors. Increased student engagement and the immediate feedback obtained during lectures were advantages commonly noted by lecturing staff. [Gauci, Dantas, Williams, & Kemm, 2009, p. 60]

In “Examining the Use of Audience Response Systems in Secondary School Classrooms: A Formative Analysis” [Kay, LeSage, & Knaack, 2010] 659 Canadian students from grade 9 to 12 and 23 teachers were surveyed after using a clicker-based ARS during their regular classrooms for three months. The students were surveyed in the final month of the ARS usage with a questionnaire consisting of 11, 7-point Likert scale questions. The survey focused on overall attitudes, student involvement, assessment and learning. An excerpt of the results of the student’s survey is listed in table 15. Secondly the use of the ARS for formative or summative assessments was evaluated. The conclusion was that “…most secondary students in this study did not respond well when the ARS was used as a test-taking device.”

Question	n	Mean	Standard deviation
I would prefer to use clickers.	653	5.3	1.8
I was more engaged in the lesson when clickers were used.	657	5.3	1.5
Using clickers was a good way to test my knowledge.	655	5.4	1.4
I liked seeing what other students in the class selected for answers.	656	4.8	1.5
I learned more when clickers were used.	656	4.4	1.5

Table 15: Quantitative student survey cited from [Kay, LeSage, & Knaack, 2010, p. 350]

In "Use of an Audience Response System to Augment Interactive Learning" [Freeman & Dobbie, 2005] a clicker-based ARS was used in a statewide faculty meeting of the University of North Carolina-affiliated family medicine residency programs. The lecturer used the ARS six-times during his/her lecture. In the end of the lecture the 46 participants were asked to evaluate the effectiveness of the ARS. 84% of the participants stated that the deployment of the ARS did make a lot more fun than traditional lecture formats. Another question was if they can consider using the ARS in their work, 44% of the participants stated that they could consider it, 33% could rather consider it, 15% could consider it only a little bit and 8% could not consider it.

2.4. Literature about integrated Audience Response Systems

After investigating requirements, interactive task types and evaluation approaches of classical Audience Response Systems, the scientific knowledgebase was examined for research about integrated Audience Response Systems i.e. for systems that combine the aspect of holding presentation and conducting interactive tasks with the audience. The following questions will be elaborated in this chapter:

- Has there been research about integrated ARS?
- Have aspects of an integrated ARS, got integrated into classic ARS?

In "Classroom Response Systems in Higher Education: Meeting User Needs With NetClick" [Abramson, Pietroszek, Chinaei, Lank, & Terry, 2013] a web-based Audience Response System got developed and evaluated. The study was conducted under the premise that the effort of authoring new content into an ARS prevents lecturers from using such a system. They developed a web-based ARS called "NetClick". A short description of the tool is cited from the reference chapter III sub-chapter A:

"NetClick.mobi was explicitly designed to address the fact that most educators in post-secondary education have a significant amount of teaching presentation material already created. The system is premised on its ability to be used without authoring new content, or even specifying interaction modes. Existing computer slides, in .pdf format (which major presentation software suites can natively output to) can be dragged and dropped onto NetClick.mobi through a browser interface: this initiates the upload and conversion process to interactive format. Once completed, the slides are now available for interactive presentation." [Abramson, Pietroszek, Chinaei, Lank, & Terry, 2013, p. 841]

The mentioned interactive format or interactive presentation describes an interactive task where the lecturer uses its uploaded slides and let the students mark points of interest. Then an overlay over the slide is displayed representing the responses of the students as heat map.

To evaluate their tool and interactive task type they conducted an interview with four lecturers. During the interviews the lecturers used the tool for a mini-lecture of one of their courses. The results were that the lecturers have to know about the response function already as they design the presentation slides, that it is hard to introduce the interactive task spontaneously for classroom interactivity and that there is a barrier of using a new slide projection tool, especially if the currently used one has some extended features, like animations or an extended lecturer view.

Although the paper focused on the interactive task, they developed an integrated Audience Response System where controlling/projecting the presentation slides and interactive tasks were merged into one system.

The reference "Classroom Response Systems in Higher Education: Meeting User Needs With NetClick" [Abramson, Pietroszek, Chinaei, Lank, & Terry, 2013] was the only paper found that covered aspects of an integrated Audience Response System, therefore this leaves a wide field open for further research on this topic. The investigation of web-based integrated Audience Response Systems is therefore the prime topic of this thesis.

3. Research Questions

After consulting the scientific knowledge bases, the main topic of the thesis arises. Due to very few contributions towards the integrated aspect of Audience Response Systems, a deeper look into this field is mandatory. In this chapter the main research questions of this thesis are proposed and described.

3.1. iARS requirements and system design

Which requirements emerge for web-based iARS and which system design fulfils them in a large scale education environment?

The first research question discusses two parts; first the requirements which emerge for a web-based integrated Audience Response System are evaluated and second it is investigated what system design can fulfil these requirements. Requirement engineering is an important part of the software development process; the resulting requirements are the basis for the following development steps. Important are requirements of an integrated Audience Response System which emerge during the different lecture process phases (e.g. preparation, presentation and post-processing). This thesis will focus on the different interactive task types an integrated Audience Response System can deliver. As one of the prime tasks of an Audience Response System is to improve the interactivity between lecturers and students during the lecture unit, the selection of suitable interactive task types for large scale education environments is essential. Additionally the requirements which emerge from the technical point of view are a topic of interest. The second part of the research question discusses how an integrated Audience Response System can be designed to fulfil these requirements in large scale education environments. For the design of the system multiple topics are important. First an architecture that fulfils the requirements shall be developed. Second a technology stack that fulfils the technical requirements and supports the proposed architecture has to be defined. To support the deployment in large scale education environments the system has to be designed with horizontal scaling in mind. Third the workflow for an integrated Audience Response System is designed, it has to fulfil the usability requirements which emerge out of the first part of the research question and assure a system that is as simple as possible for the users.

3.2. iARS prototype evaluation

Which methods are suitable to evaluate web-based iARS prototypes in a large scale education environment?

The second research question discusses which methods are applicable to evaluate prototypes of integrated Audience Response Systems. Evaluation of a system is an important part in scientific research. Finding suitable evaluation methods for the prototypes which are developed to answer the first research question is crucial for the ability to answer the first research question correctly. To evaluate which methods are suitable, different methods, in context of data collection and evaluation, have to be deployed and assessed. Due to the two user groups of an integrated Audience Response System, namely the lecturers and the students, it has to be investigated if different evaluation methods are needed for the different groups. Another problem is the context of this question, the evaluation in large scale education environments. Because there are potentially a lot of students in one lecture unit suitable evaluation methods have to be found to cover the amount of potential research subjects.

3.3. iARS lecturers survey

Which insights can be gained from currently established lecture processes and is there a demand for an iARS in university education?

The third research question discusses the demand for integrated Audience Response Systems in university education. Beside the elaboration of requirements, system design and evaluation of integrated Audience Response Systems the actual demand will be evaluated. Other topics of interest are the past experience of the lecturers with Audience Response Systems, the current lecture preparation processes and the current lecture presentation processes. As the use of an integrated Audience Response System requires a different preparation and presentation process for the lecturer, it is important to know the currently established lecture processes. Thereby a transition to an integrated Audience Response System can be better planned for the lecturers. Additionally the preferences of the lecturers for different interactive task types provided by the integrated Audience Response System will be evaluated. The demand for specific requirements of an integrated Audience Response System will be investigated for a better understanding of the lecturers.

4. Research Approach

In this chapter the methodology of the research is explained. The chapter is structured according to the research questions. The last sub-chapter represents the research process graphically and defines the structure of the following chapters.

4.1. iARS requirements

The following steps will be applied to answer the research question about the requirements of an integrated Audience Response System.

4.1.1. Initial requirements from literature

The requirements of the literature are summarized and categorized. Requirements not related to the development of an integrated Audience Response System get sorted out. Additionally the different interactive task types which were found in literature are summarized. The contribution of this chapter contains two tables listing the requirements and the interactive task types from the literature.

4.1.2. Expert discussion for an integrated ARS

After the requirements from the literature are stated, the requirements for the prototype development are described. Additional requirements emerge from an expert discussion and get combined with the requirements from literature. The contribution of this chapter contains a description of each requirement and a summary table listing all requirements for the prototype development.

4.1.3. Improved requirements

After the first prototype was evaluated during a pilot test, the emerged feedback of the test is transformed into new requirements. The initial requirements from the chapter before and the new requirements of the pilot test are discussed by experts. The contribution of this chapter contains a description of each new requirement and a summary table listing all requirements for the improved prototype development.

4.2. iARS system design

The development process is executed as iterative software development process. Because a new class of Audience Response Systems is investigated, the development of a prototype contains many unknown variables. Therefore the requirements cannot be fixed at the beginning of the development process and are subjects to changes. Thus an agile software development process is deployed to encounter this risk. The main focus of the development process is the continuous improvement of the deployed tool so the process is based on an iterative spiral model [Boehm, 1988, p. 64]. Additionally the development process has characteristics of a PDCA-Cycle [Moen & Norman, 2006, p. 9]. Figure 2 visualizes the characteristics of one cycle in the prototype development process.

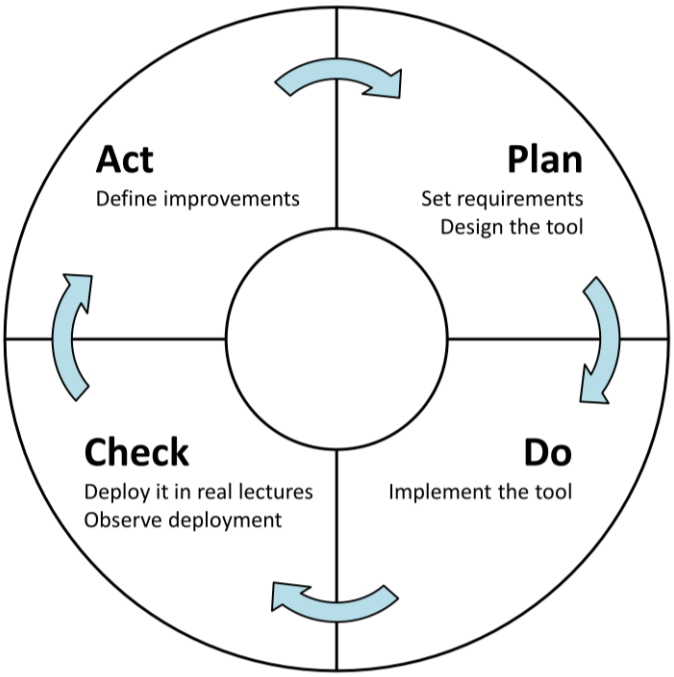


Figure 2: Prototype development cycle cf. [Moen & Norman, 2006, p. 9]

The cycle starts with setting the requirements and designing the tool. Then the tool gets implemented. After these process steps the emerging tool is evaluated and observed in real world scenarios. Afterwards improvements are defined, which emerges from the deployment observation. This thesis describes the realization of the first and the second iteration cycle in the development process.

4.2.1. Prototype development

After the expert discussion the integrated Audience Response System prototype is implemented. The contribution of this chapter contains a description of the prototype architecture, the used technology stack to fulfil the requirements and the designed workflow of the system. To improve the understanding of the architecture and the workflow both are graphically visualized.

4.2.2. Improved prototype development

After the pilot test of the first prototype was conducted and the requirements for the improved prototype were defined, the improved integrated ARS prototype is implemented. The contribution of this chapter contains a description of the changes between the first and improved prototype's architecture, technology stack and workflow. The changes are graphically visualized.

4.3. iARS prototype evaluation

The following steps will be applied to answer the research question about the evaluation of an integrated Audience Response System.

4.3.1. Pilot test

After the implementation the first prototype gets evaluated during a pilot test. The pilot test consists of deploying the tool during multiple lecture units of a single lecture course. The usage of the prototype is observed during the lectures. To gather feedback the lecturers and students are invited to give feedback about the tool after the lectures. The contribution of this chapter contains a qualitative description of the observations, the feedback from the lecturers and the feedback from the students.

4.3.2. Case study

After the improved prototype is implemented, it is deployed in different lecture courses and multiple lecture units. As in the pilot test of the first prototype, the usage of the improved prototype is observed during the lectures. In addition to qualitative feedback from the lecturers and students, a survey for the students is conducted to collect quantitative feedback. Therefore the improved prototype is evaluated with two different methods. The contribution of this chapter contains a qualitative description of the observations and the results of the students' survey.

In addition to the tool evaluation a survey for the lecturers is conducted. The survey is deployed to receive insight to the past experience with ARS, the current lecture preparation and presentation process, preference for different interactive task types and the willingness to use an ARS/iARS. The contribution of this chapter contains the results of the lecturers' survey.

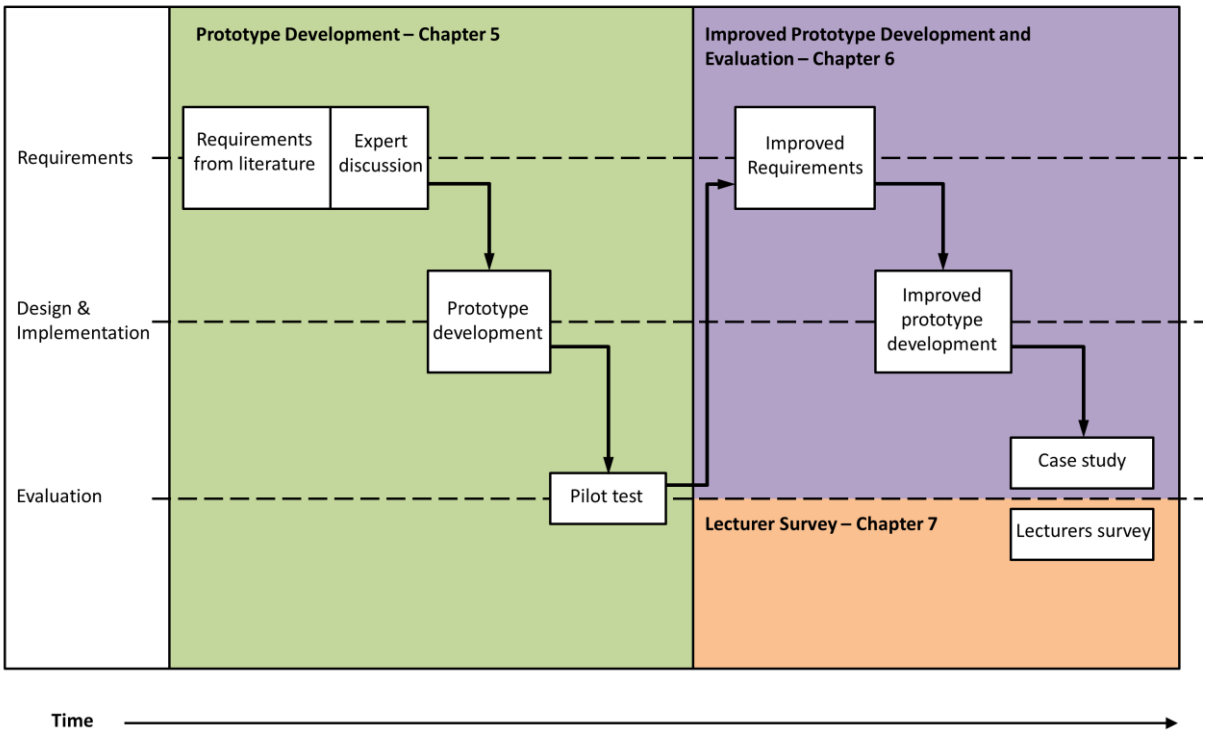


Figure 3: Research approach

The described research approach is visualized in figure 3. The diagram shows the chronological order of each research step. Items that contribute to the same research question are drawn at the same horizontal line. The arrows in the figure represent which step contributes data to another research step. Additionally the graphic represents which research items are grouped together to form one of the following chapters of this thesis.

5. Prototype Development and Evaluation

After the scientific literature had been consulted to find existing requirements for Audience Response Systems, the acquired requirements were summarized and used as base for the prototype development. Then the prototype was implemented and evaluated under real world conditions in a pilot test.

5.1. Initial requirements from literature

To summarize the requirements some data cleaning processes have been applied. First the requirements that focused on clicker based ARS or non-web based ARS have been sorted out. Long requirement descriptions have been condensed to their essence and formulated into a short statement. The terminology has been normalized, i.e. the term lecturer is used instead of professor or creator, the term student is used instead of audience or user, the term interactive task is used instead of question, survey or answer.

The requirements are categorized into the following groups: The first group contains technical requirements, which represent items that belong to the overall system or technical implementation. Interactive tasks requirements include items that can be assigned to the preparation or the execution of interactive tasks. Presentation slide requirements contain items that can be dedicated to the display, control or change of the presentation slides. Post-processing requirements include items which are relevant after the lecture has been held.

The cleaned, normalized and categorized requirements from the literature are listed in table 16. A detail description for requirements which are chosen for the first prototype development is listed in chapter 5.2.

Another important aspect of an Audience Response System, beside the requirements listed above, are the offered interactive task types. To support the decision which interactive task types will be implemented in the prototype, the occurrences of each type in the available literature were counted. Table 10 is referenced from the related work chapter and shows how often an interactive task type was found in the literature and public available ARS tools, sorted by occurrence.

Interactive task type	Total from table 8	Total from table 9	Sum of totals	Sum in %
Single-/Multiple-Choice Survey	6	12	18	90%
Open Question	2	7	9	45%
Quiz	3	5	8	40%
Sort / Rank	2	2	4	20%
Region of Interest / Heat Map	2	1	3	15%
True / False	1	2	3	15%
Draw / Sketch	2	-	2	10%
Scale / Numeric	1	-	1	5%

Table 10: Summary of interactive task types

Requirements	Literature
Technical requirements	
The lecturer can use the system anonymously.	[15]
The students can answer anonymously.	[15],[19]
The students have a quick and easy access to the webpage, where they can participate in interactive tasks. The webpage has a short URL.	[15]
Interactive tasks requirements	
The lecturer can start and stop the interactive tasks.	[15]
The lecturer can choose whether to show results during the interactive task or only when the task has been finished.	[15],[16]
During the interactive task, students can answer again.	[15]
The lecturer can pose multiple interactive tasks during the same lecture.	[15],[19]
The interactive task can be closed in two ways: stopped by lecturer or by time setting (the lecturer can add more time on the fly).	[16]
After the interactive task is finished, the lecturer can re-continue the task.	[16]
The lecturer can re-run the same interactive task several times for different audiences. The lecturer can compare the results of the different runs.	[16]
The results of the interactive task survey show the number and percent of votes for each answer item.	[19]
The results of the interactive task survey are visualized as bar chart.	[19]
Presentation slides requirements	
The lecturers can upload their presentation slides as PDF files.	[18]
Once connected to a presentation, each student sees the currently displayed slide on their device.	[18]
The lecturer can navigate through the slides by using the arrow keys.	[18]
Students cannot advance forward past the currently displayed slide.	[18]
The URL, which enables the students to join the presentation, is displayed on a toolbar that is visible for the first slides of the presentation.	[18]
Following an interactive task, the lecturer may either hide the result overlay by clicking a toggle and return to the current slide, or advance to the next slide.	[18]
Post-processing requirements	
The lecturer can download the results of the interactive tasks.	[15],[16]

Table 16: Requirements from literature

5.2. Expert discussion for an integrated ARS

After the requirements from the literature were summarized, the requirements for the integrated Audience Response System prototype are discussed. A brainstorm session [Clark, 1989] was conducted, discussing which requirements should be taken from literature for the first prototype. Additionally a distributed approach had been used to collect, elicit and condense additional requirements for the first prototype. The key requirements listed in table 17 were emerging after the brainstorm session. The requirements are marked whether they have references to requirements from the literature research or where emerging from the brainstorm session.

Prototype requirements	From literature	From session
Technical requirements		
The students can answer anonymously.	X	
The students have a quick and easy access to the webpage, where they can participate in interactive tasks. The webpage has a short URL.	X	
The system supports internationalization and is localized in English and German.		X
The system distributes lecture actions and student answers with low latency.		X
The system supports multiple device classes (i.e. laptop and tablet).		X
The system supports at least 100 students, using the system concurrently.		X
Interactive task type requirements		
The lecturer can prepare surveys to poll the students with single and multiple choice questions.	X	
The lecturer can prepare open questions to get short free typed answers from the students.	X	
Interactive task requirements		
The lecturer can start and stop the interactive tasks.	X	
The lecturer can pose multiple interactive tasks during the same lecture.	X	
The results of the interactive task survey show the number and percent of votes for each answer item.	X	
The lecturer can prepare interactive tasks for a lecture.		X
Presentation slides requirements		
The lecturers can upload their presentation slides as PDF files.	X	
The lecturer can navigate through the slides by using a keyboard or on screen control buttons.	X	
Once connected to a presentation, each student sees the currently displayed slide on their device.	X	
Students cannot advance forward past the currently displayed slide of the lecturer.	X	
The lecturer can set the visibility of a presentation to public or private.		X
The system provides one view for the presentation projection and one for the lecturer's laptop/tablet for controlling the interactive tasks.		X
Post-processing requirements		
The system supports downloading of the interactive task results as CSV files.	X	

Table 17: Prototype requirements

Technical requirements

The students can answer anonymously. This should help raising the participation of the students in interactive tasks. Without the fear of being socially penalized for giving a wrong or other answer, the barrier of using the system should be lowered.

The students have a quick and easy access to the webpage, where they can participate in interactive tasks. The webpage has a short URL. The students have to find their website as simple and fast as possible. To lower the barrier an automatically generated 4-digit short URL should be provided that can be typed in easily in each supported device.

The system supports internationalization and is localized in English and German. As the cultural diversity is high in nowadays lecture classes the language barrier cannot be ignored. German has been chosen because it is the native language in most fields of study offered by Vienna University of Technology. English has been chosen as second language because of its global spreading and its status as native language for informatics and scientific research.

The system distributes lecture actions and students answers with low latency. Low latency is an important part of the user experience. A lecture action, like a change to the next slide, must be fast propagated to the presentation projection and to all audience clients.

The system supports multiple device classes (Laptop, Tablet). Due to heterogeneous device distribution with different capabilities, the system has to support each device and remain functional nevertheless. To limit the effort for the first iteration only typical laptop and tablet sizes are considered.

The system supports at least 100 students, using the system concurrently. As an Audience Response System will be deployed in large lectures and courses it should support as much concurrent users as technical possible. To limit the effort and resources for the first iteration the goal is to support about 100 students using the system concurrently.

Interactive task type requirements

The lecturer can prepare surveys to poll the students with single and multiple choice questions. The lecturer can prepare open questions to get short and free typed answers from the students. The interactive task types that get implemented into the prototype have been chosen through the ranking of table 10. To prohibit a too strong focus on the interactive task types for the first prototype iteration, the amount of different types has been limited to two. Therefore the interactive task type's survey and open question will be implemented.

Interactive Task requirements

The lecturer can start and stop the interactive tasks. The lecturer controls when to start and when to stop an interactive task.

The lecturer can pose multiple interactive tasks during the same lecture. Allowing more than one interactive tasks during the lecture seems to be a legit requirement.

The results of the interactive task survey show the number and percent of votes for each answer item. It is important to rate the significance of the survey result, especially if it's a multiple choice survey where the percentages of the answer options does not sum up to 100%.

The lecturer can prepare interactive tasks for a lecture. Preparing the interactive tasks before the lecture saves the lecturer time during the often tightly scheduled lecture unit. Additionally the lecturer can consider before the lecture what question or type of interactivity he/she will pose at what time to the students.

Presentation slides requirements

The lecturers can upload their presentation slides as PDF files. Assuming that most of the lecturers present or could present their presentation slides directly as PDF, the restriction to PDF files seems acceptable.

The lecturer can navigate through the slides by using a keyboard or on screen control buttons. For the first iteration of the prototype, controlling the presentation slides is limited to the arrow keys of a keyboard and to on screen control buttons.

Once connected to a presentation, each student sees the currently displayed slide on their device. The students can therefore follow the presentation during the times where no interactive task is active.

Students cannot advance forward past the currently displayed slide of the lecturer. This restriction prevents spoiling of presentation content, e.g. see the answer to interactive tasks a priori or reveal conclusions that need further explanation from the lecturer.

The lecturer can set the visibility of a presentation to public or private. This requirement allows the lecturer to fully prepare a presentation privately and publish it when he/she is holding the lecture.

The system provides one view for the presentation projection and one for the lecturer's laptop/tablet for controlling the interactive tasks. The first view only shows the current presentation slide and should be presented via a projector device, like a beamer. The second view is designated for the lecturer device (i.e. laptop or tablet) and controls the presentation slides and interactive tasks.

Post-processing requirements

The system supports downloading of the interactive task results as CSV file. This allows the lecturer to export the results of the interactive task to a spread sheet program and further evaluate the result data.

5.3. Prototype development

After the requirements were defined, the development of the prototype started. The working title of the project is “Presentr” and the logo is shown in figure 4.

Figure 4: Prototype logo

Architecture

The starting point of the architecture design was the standard web application architecture for rich web applications. Applying a value-based approach cf. [Biffl, Aurum, Boehm, Erdogmus, & Grünbacher, 2006] and the risk that additional components may add more latency to the system, which contradicts with the low latency requirement, the system design has been developed low-latency-driven. The architecture, visualized in figure 5, represents the resulting architecture design. It extends the standard web application architecture for rich web applications by using RESTful services and web sockets as extension for real-time communication. The architecture consist of two parts the server and the client part. Both parts communicate with each other over the internet.

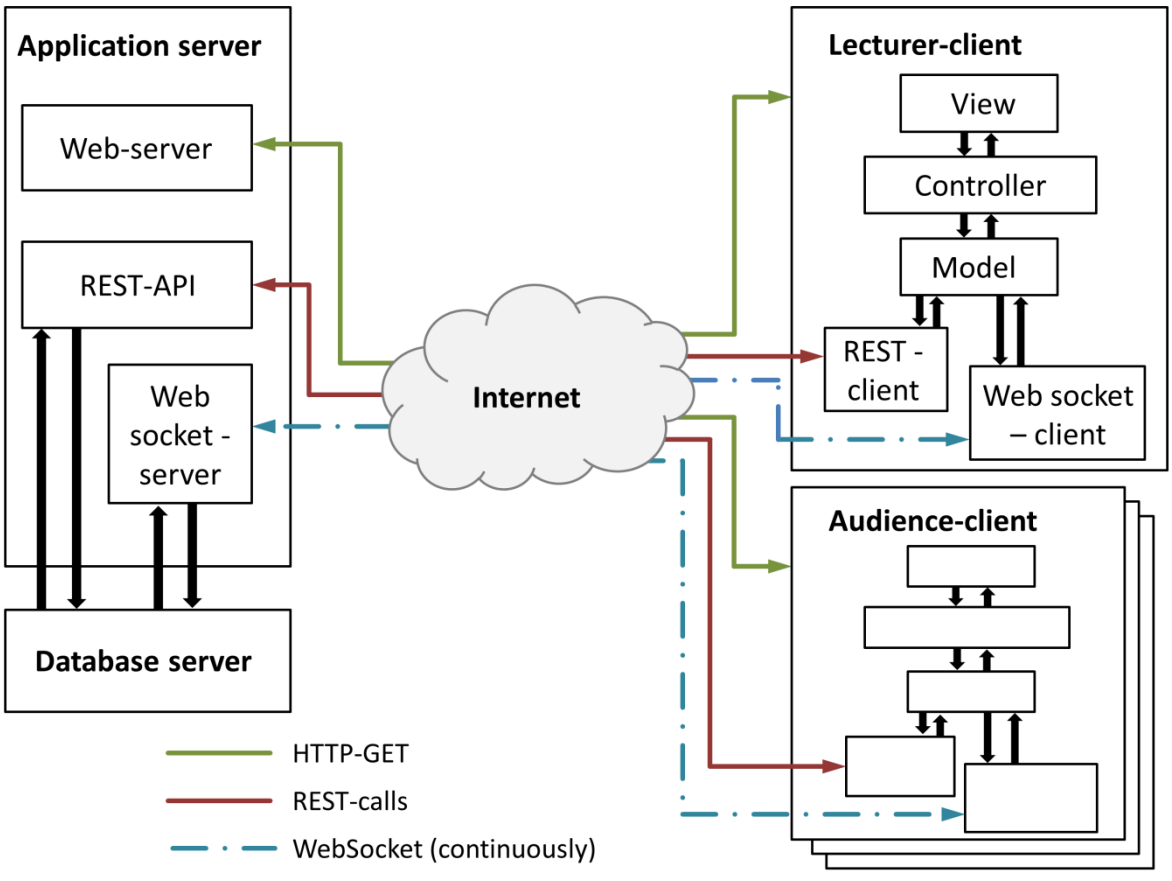


Figure 5: Prototype Architecture

The server can be separated into an application and a database server. The application server provides the business logic of the system, while the database server provides a persistence layer. The application server consists of three parts, a web server, a REST-API and a web socket server. The webserver is responsible for deploying the static parts of the client to the student’s web browsers.

The REST-API provides structured and controlled access to the persistence layer for the clients. Finally the web socket server provides an interface for real-time socket communication with the web browsers of the students.

The client part of the system can be conceptually separated into the lecturer client and the audience client. The lecturer client is the user interface for the lecturers controlling their presentation slides and interactive tasks. The audience clients are the user interfaces for the students providing the capability to follow the presentation slides and participate in interactive tasks. Both clients are using the Model-View-Controller paradigm [Krasner & Pope, 1988] for separation of concerns, modularity and cleaner code.

There is no direct communication between the lecturer and audience clients. All clients are communicating directly with the server, which propagates the information further to the clients as needed.

Technology stack

For the prototype the following technologies have been used. The explanations follow the structure of the architecture as shown in figure 5.

The application server is implemented with Node.js[12], providing an event-driven, non-blocking I/O model. Node.js is designed to build scalable network applications, with many concurrently handled connections. Instead of the concurrency model of multiple operating system threads, an asynchronous event driven framework is used in Node.js. All I/O operations like database queries are asynchronous and non-blocking. This model is well suitable for web applications that require moderate access to the persistence layer and only short and cheap server side calculations. Additional Express[13], a module of Node.js, provides a framework for session and cookie handling and an easy interface for building a REST-API. For implementation the programming language JavaScript[14], the same programming language as on client side, is used.

As persistence layer the NoSQL database MongoDB[15] is used. MongoDB is a document-oriented database, that structures data in documents with dynamic schemas instead of the standard SQL oriented table-based relational structures. In combination with Node.js, MongoDB offers a fast and easy way to save and retrieve JavaScript-Objects without writing SQL-Queries. Additionally MongoDB supports sharding for scaling horizontally.

For near real-time interaction and low latency, between actions of the lecturer or answers from the students, WebSockets[16] are introduced. For the integration with Node.js and for the support of older browsers, that lack of WebSockets support, the library Socket.IO[17] is used. Socket.IO provides a number of features that makes the handling of WebSockets easier, like fallback mechanisms (e.g. long HTTP polling), broadcasting to multiple sockets or storing data for each connected client. It follows an event-driven model, like Node.js, which allows an easy integration.

[12] **Node.js.** https://nodejs.org
[13] **Express.** http://expressjs.com
[14] **JavaScript.** http://www.ecma-international.org/publications/standards/Ecma-262.htm
[15] **MongoDB.** https://www.mongodb.org
[16] **WebSockets.** https://tools.ietf.org/html/rfc6455
[17] **Socket.IO.** http://socket.io

The client side, consisting of the lecturer and audience client, is realized as HTML5[18] user interface. The design is optimized for laptop and tablet usage, as stated in the requirements, through the use of the Bootstrap[19] framework. To realize a rich and dynamic web application the JavaScript framework AngularJS[20] is used. AngularJS, which follows the MVC paradigm, is used to mitigate the problem that HTML was originally not designed for dynamic content and views. It provides features for code reusability and modularization, binds view elements to underlying data objects and separates the front-end from client business logic and server communication.

To render PDF's in the lecturer and audience clients, the JavaScript library PDF.js[21] is used. PDF.js renders PDF files into a HTML5 canvas element and is independent from a browser's built-in PDF viewer.

The client is requested from the web-browser of the users (lecturer and students). While preparing a presentation (e.g. upload a presentation, prepare interactive tasks) the REST-API is used for persisting additions and changes. During a lecture the lecturer and audience clients are communicating through WebSocket connections for minimal latency.

[18] **HTML5.** https://www.w3.org/TR/html5
[19] **Bootstrap.** http://getbootstrap.com
[20] **AngularJS.** https://angularjs.org
[21] **PDF.js.** https://mozilla.github.io/pdf.js

Workflow

For the first iteration of the prototype an account for the lecturers was created. The students have to register with a self-chosen username and password. The device of the lecturer has to be configured with the projector device (e.g. beamer) as extended desktop to allow all functionalities during the lecture.

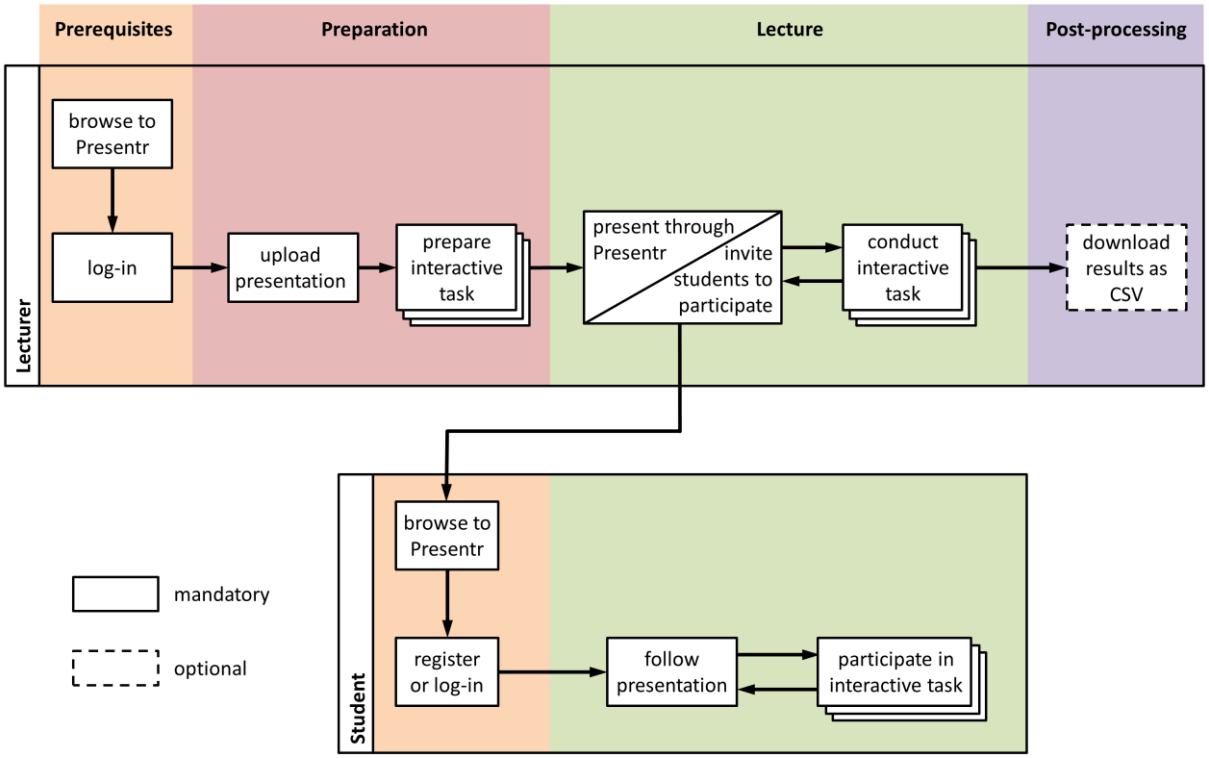


Figure 6: Prototype Workflow

The workflow of the system can be split into the workflow of the lecturers and the workflow of the students. Figure 6 visualizes the work flow of the prototype both for the lecturer and for the student. The workflows for the lecturer and for the students are described in detail below.

Lecturer workflow

1. The lecturer browses to Presentr
2. The lecturer logs-in
3. The lecturer uploads its presentation slides as PDF file
4. The lecturer prepares the interactive tasks
5. The lecturer holds his/her lecture through Presentr and invites the students to participate through the provided URL
6. The lecturer uses the prepared interactive tasks during the lecture
7. The lecturer can optionally download the results of the interactive tasks

The lecturer browses to Presentr. The lecturer uses a web browser and opens the URL under which the prototype has been published. The prototype was published under the public domain http://presentr.at

The lecturer logs-in, if not already logged in. If the lecturer visits the web application the first time he/she has to log in with the provided account credentials.

The lecturer uploads his/her presentation slides as PDF file. After the log-in the lecturer can upload his/her presentation slide. It is possible to upload a single presentation via the login button and the following selection dialog or to upload multiple presentations at once through a drag-and-drop functionality. Figure 7 shows the drag-and-drop upload process; figure 8 represents the presentation overview of the lecturer after he/she had uploaded 3 presentations.

The lecturer prepares the interactive tasks. After the upload of a presentation, the lecturer can prepare interactive tasks through the presentations detail view. The first iteration of the prototype provides the interactive task types single- and multiple-choice survey and open question. Figure 9 shows the preparation of a multiple-choice survey, figure 10 the preparation of an open question.

The lecturer holds his/her lecture through Presentr. After the lecturer prepared interactive tasks, the presentation is presented through Presentr. The lecturer opens the projector view, which is created in a separate browser tab and displays it on the projector device. Then the lecturer opens the laptop view for its device. Figure 11 shows the laptop view for a presentation with 3 prepared interactive tasks.

The lecturer invites the students to participate through the provided URL. The lecturer has to guide the students to the URL provided by the system. In the first iteration of the prototype the URL was http://presentr.at/code where “code” is a placeholder for a system-generated random alphanumeric 4 digit number. For the pilot tests the lecturer provided the URL on the blackboard of the lecture rooms.

The lecturer uses the prepared interactive tasks during the lecture. During the lecture the lecturer can start an interactive task at any time via a click on the start button. After the task has started the students see the interactive task and can respond. Figure 12 illustrates an active interactive task of the type open question with several answers from the students.

The lecturer can optionally download the results of the interactive tasks. After the lecture has finished and the interactive tasks have been used, the lecturer can download the response data from the students as CSV file. For the interactive task survey the lecturer gets the absolute votes and percentages for each answer item. For the interactive task open question the lecturer can download all answers from the students.

To produce the following screenshots the presentation slides were provided by Stefan Biffl and Dietmar Winkler from the course “Software Qualitätssicherung”[22] (software quality management).

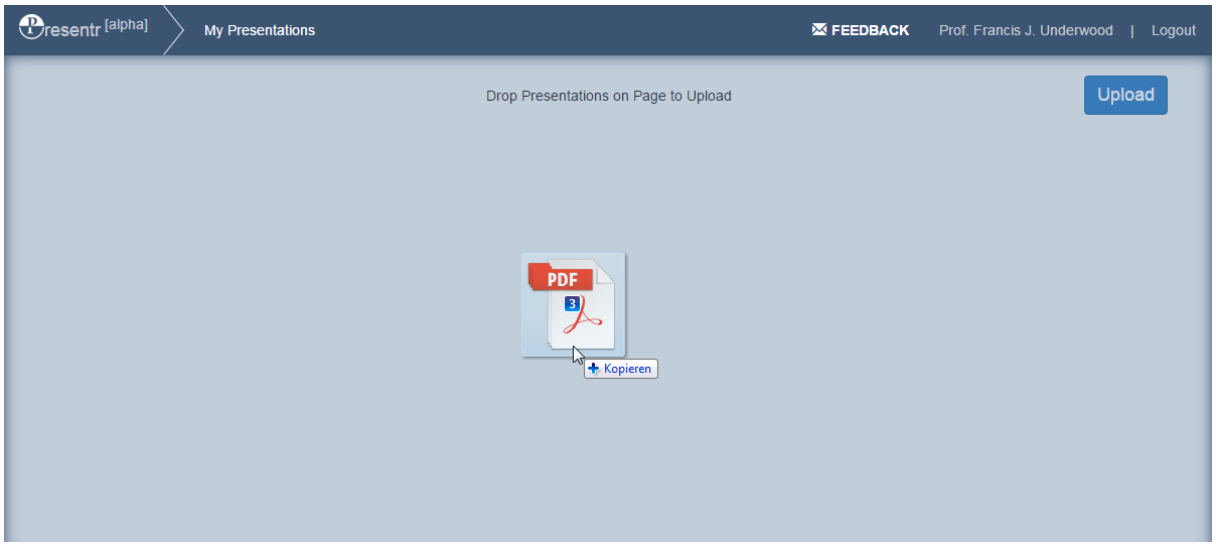


Figure 7: Prototype screenshot, upload process

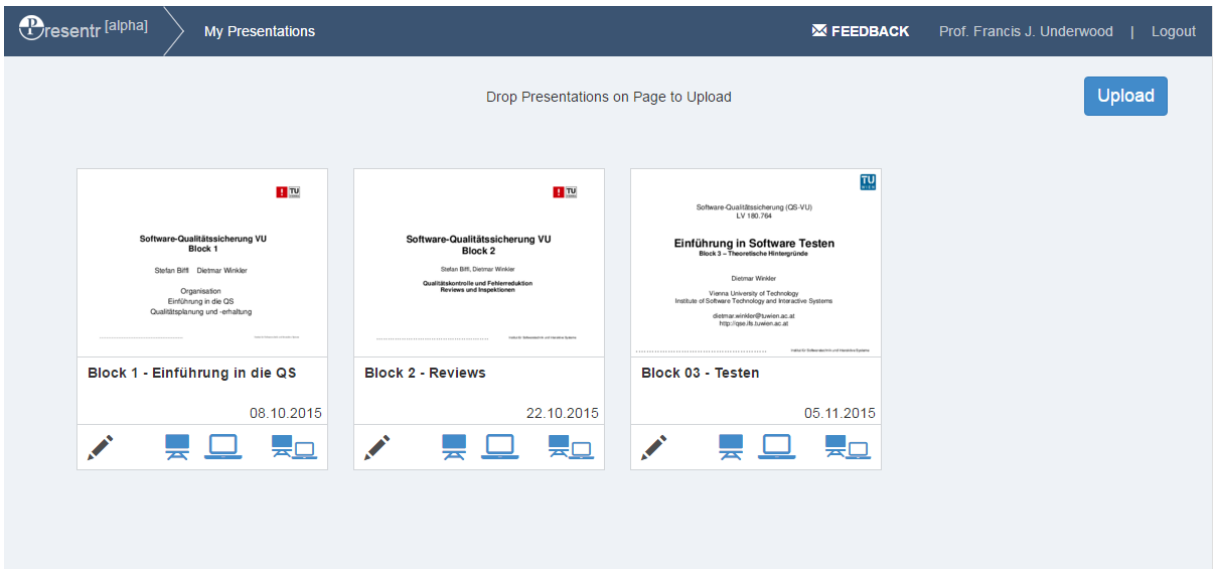


Figure 8: Prototype screenshot, presentation overview

[22] **Software Qualitätssicherung.** https://tuwel.tuwien.ac.at/course/view.php?id=6958

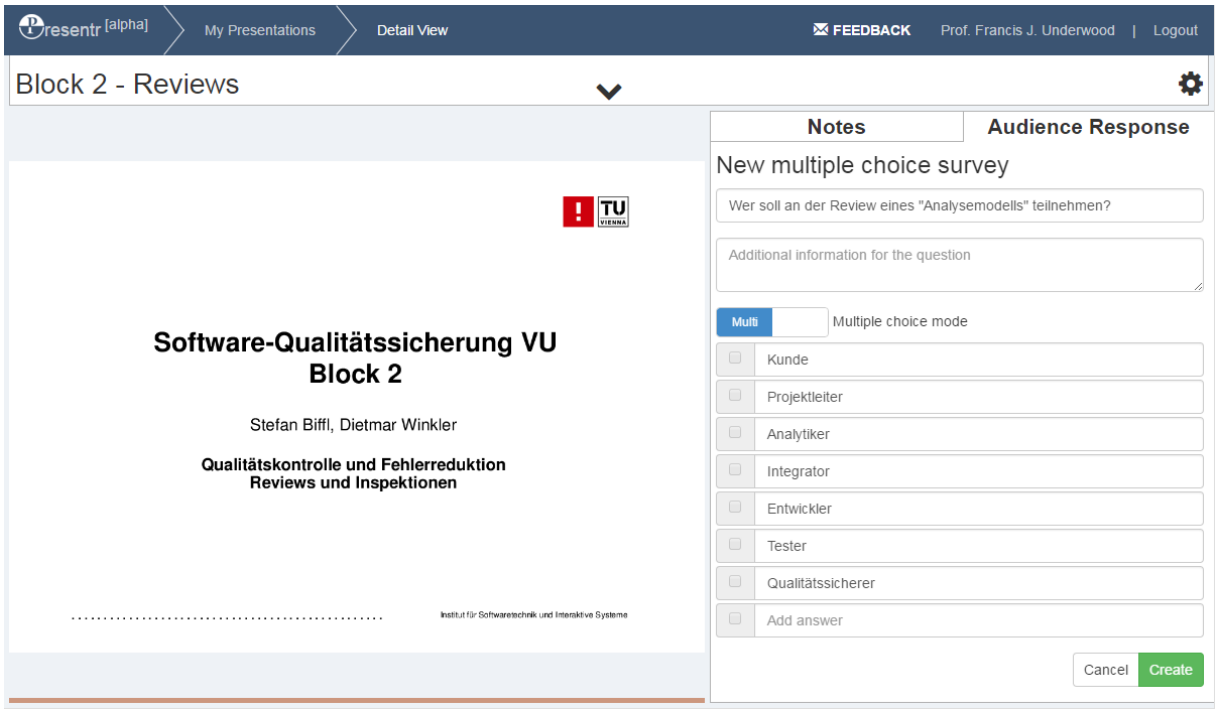


Figure 9: Prototype screenshot, preparation of survey

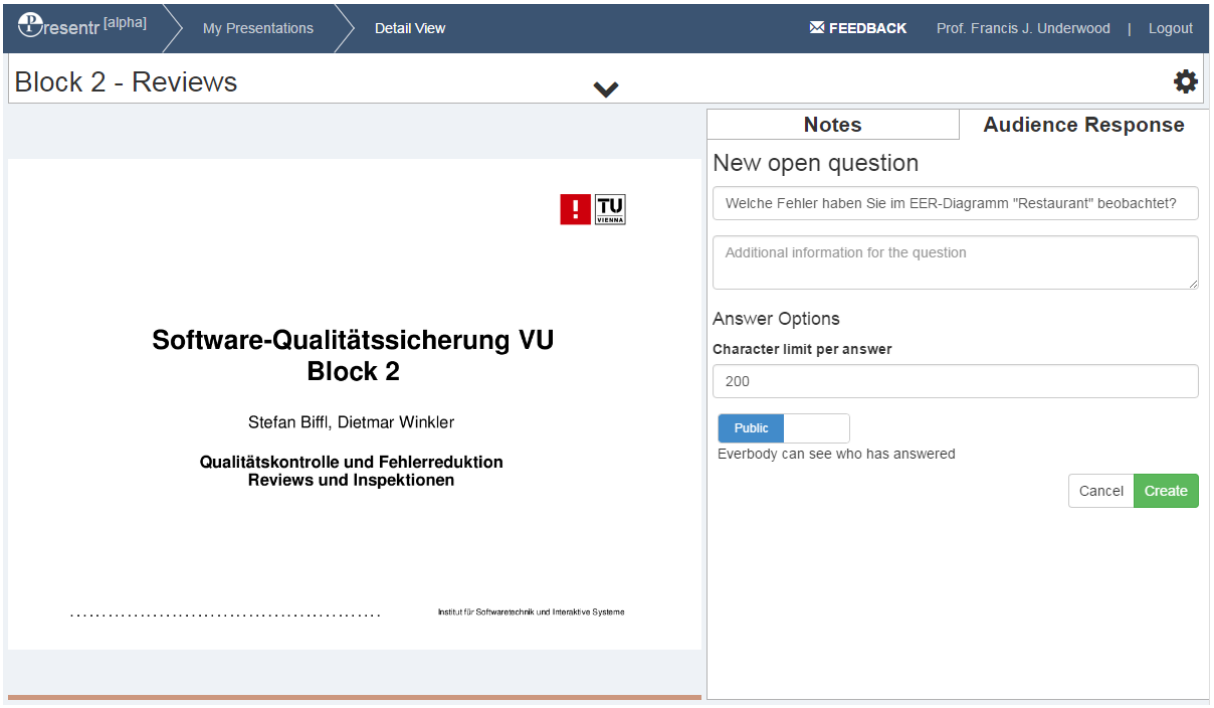


Figure 10: Prototype screenshot, preparation of open question

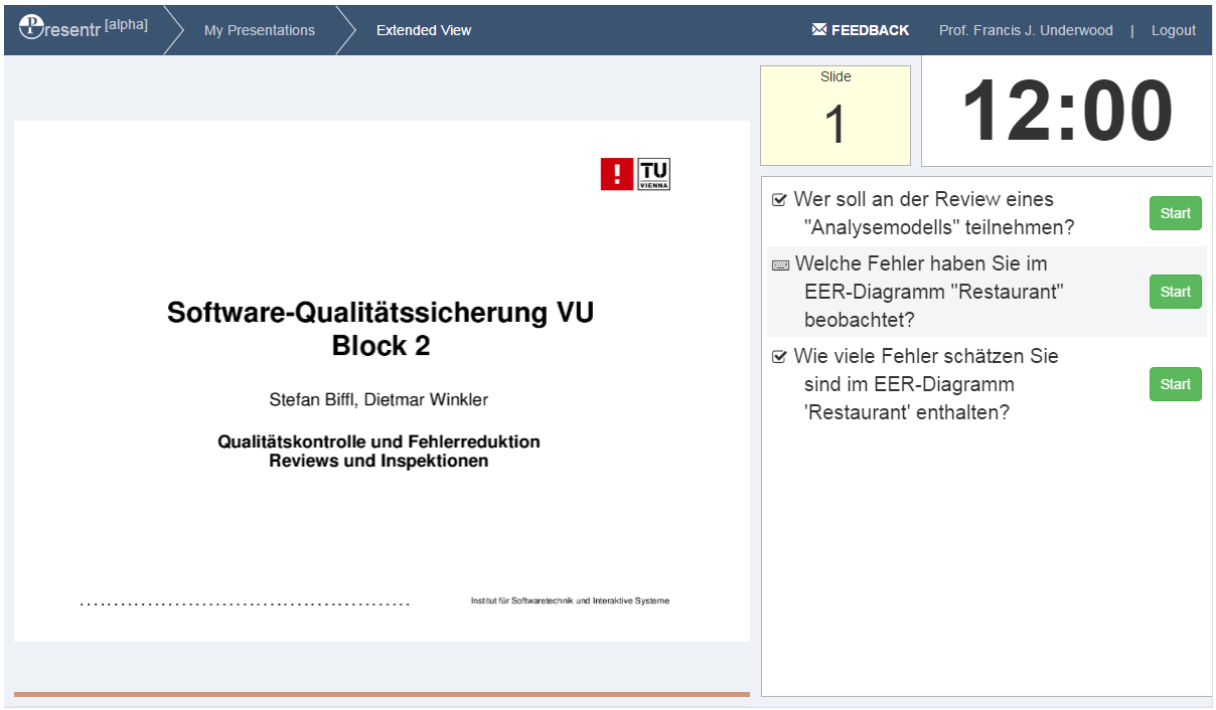


Figure 11: Prototype screenshot, laptop view

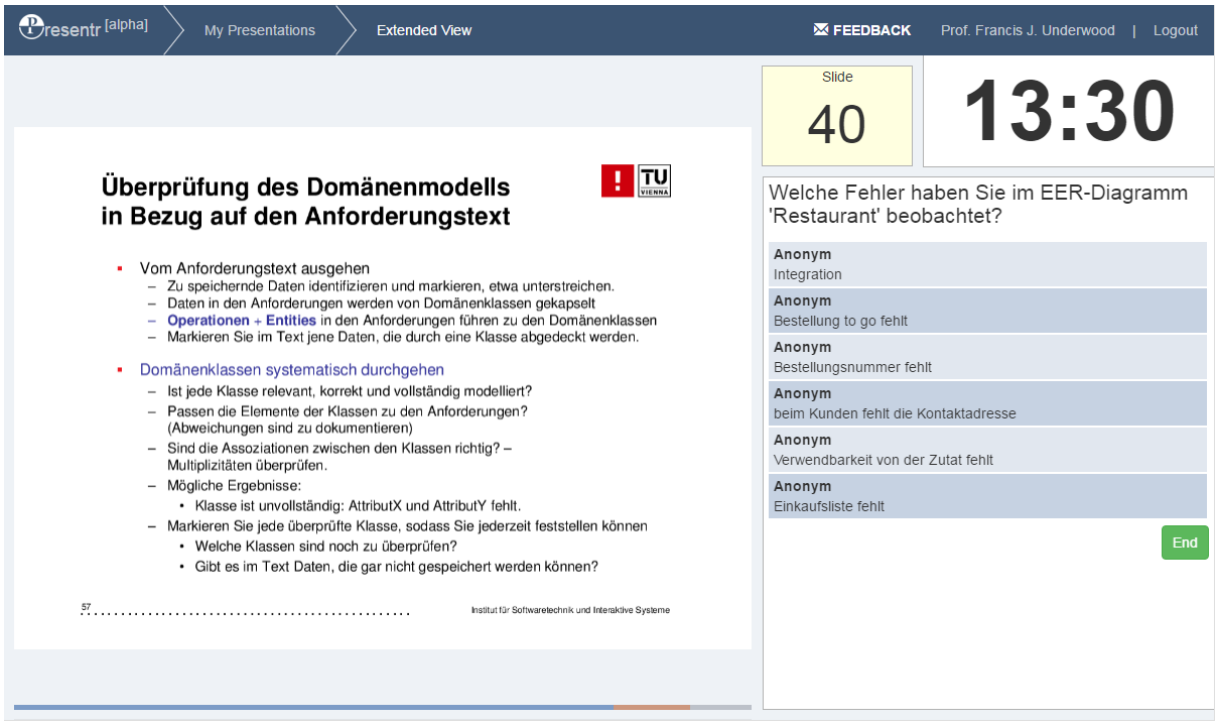


Figure 12: Prototype screenshot, result of open question

Student workflow

1. The student browses to the URL provided from the lecturer
2. The student registers or logs-in
3. The student follows the presentation
4. The student participates in interactive tasks

The student browses to the URL provided from the lecturer. The student uses the web browser on his/her laptop or tablet and opens the URL provided by the lecturer. As mentioned before during the pilot tests the URL was written on the blackboard of the lecture rooms.

The student registers or logs-in, if not already logged in. If the student visits the web application the first time he/she has to register with a self-chosen username and password or if it's not the first visit log in with the chosen account credentials.

The student follows the presentation. After the student is logged in he/she can follow the presentation of the lecturer. The student can navigate through the slides with the restriction of not advancing further then the backmost slide already presented by the lecturer. Figure 13 shows the view for the students and the warning, which pops up if the student, tries to surpass the backmost slide.

The student participates in interactive tasks. When the lecturer opens an interactive task the student can see the questions and, if it's a survey, possible answer options. Figure 14 shows an active, but not yet answered, interactive task of the type multiple-choice survey; figure 15 shows an active, but not yet answered, interactive task of the type open answer. The student view of the result for the interactive task survey is shown in figure 16.

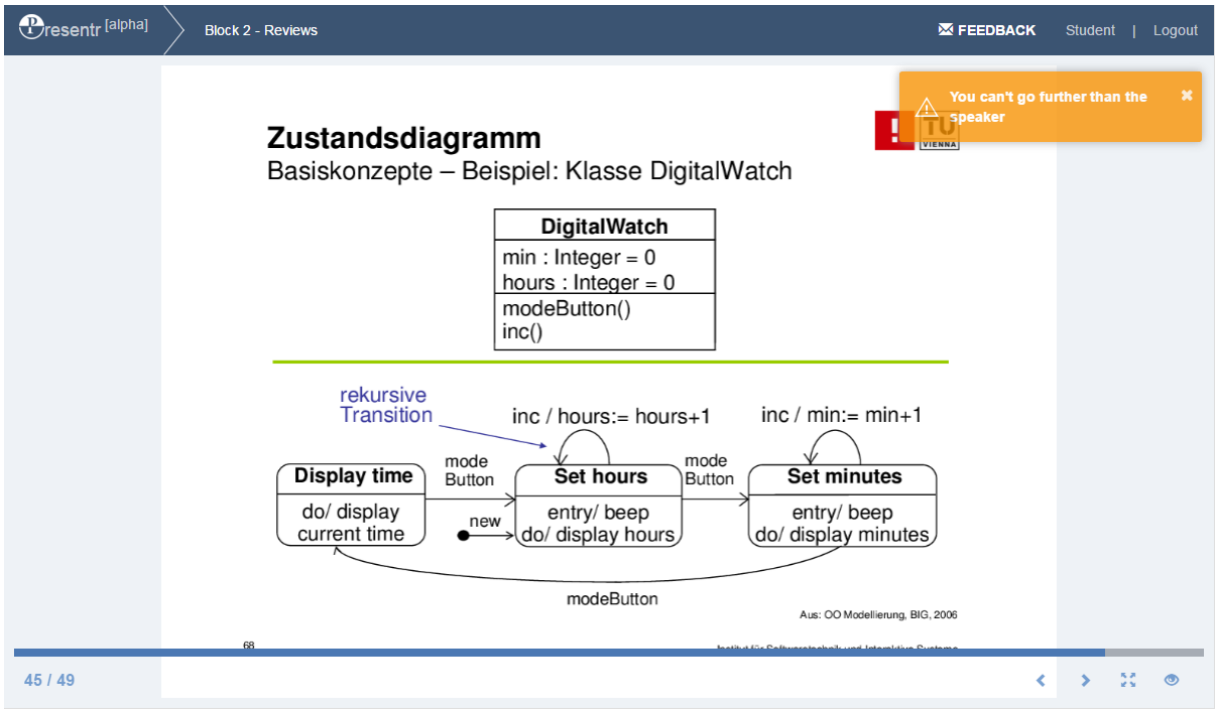


Figure 13: Prototype screenshot, student view

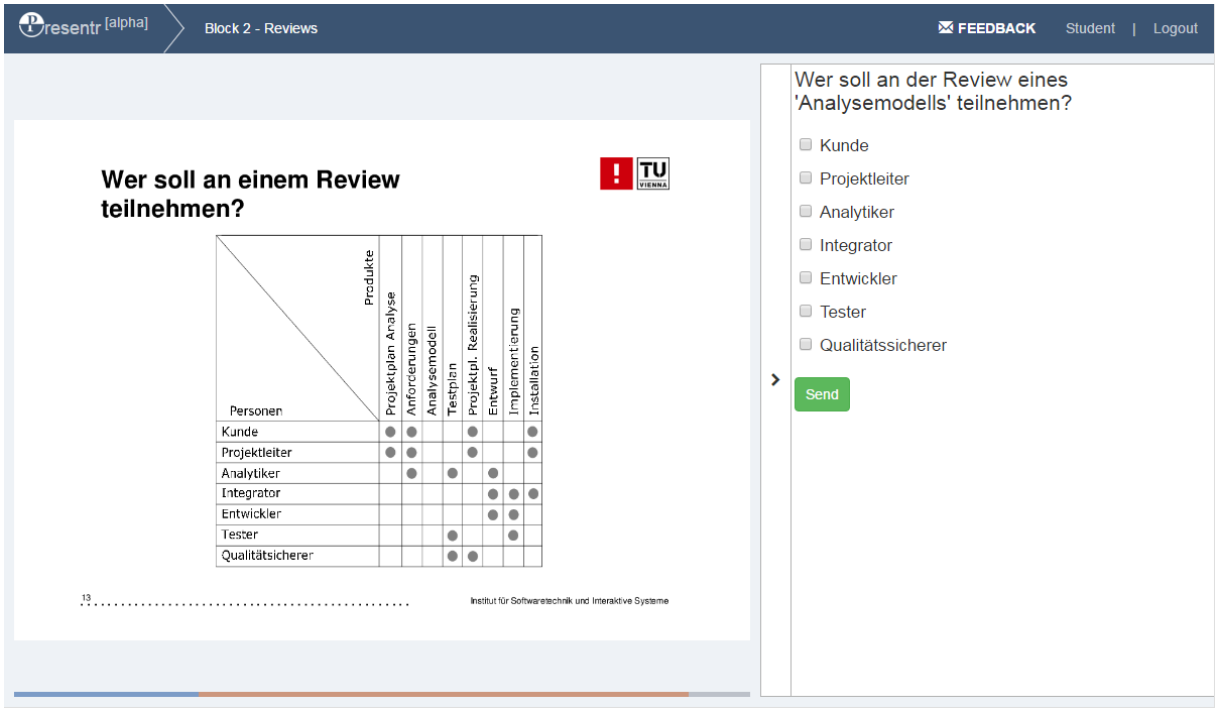


Figure 14: Prototype screenshot, student view of an active survey

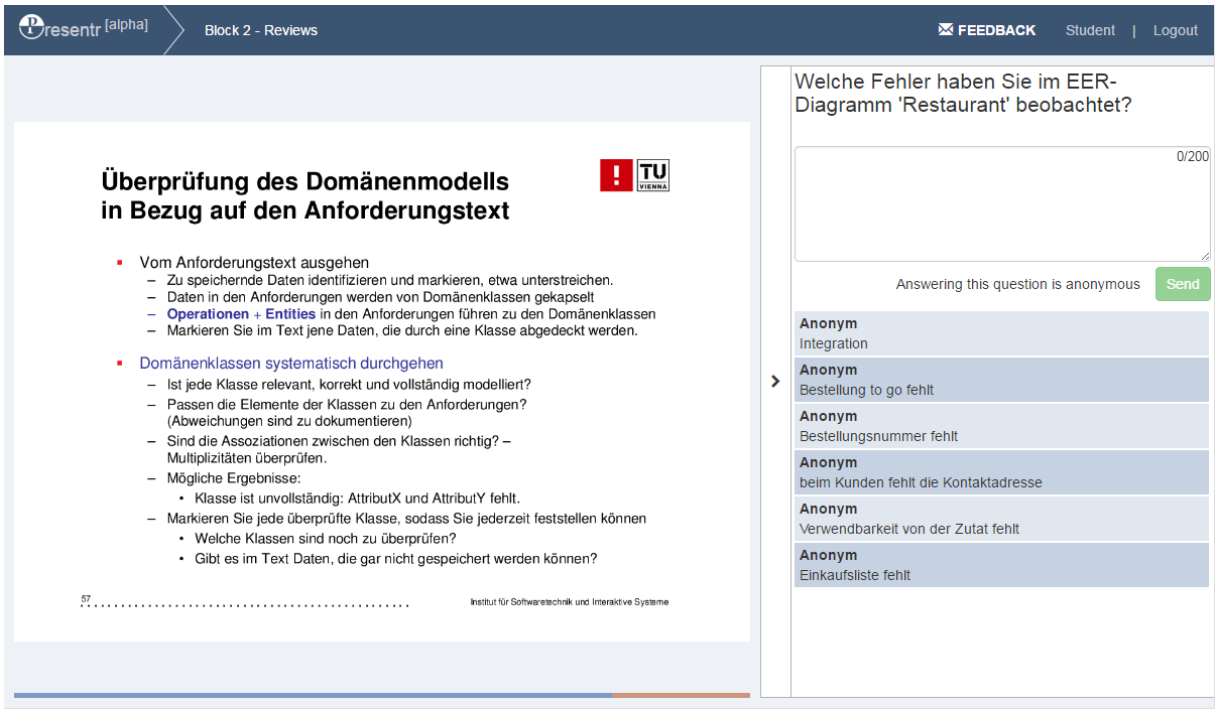


Figure 15: Prototype screenshot, student view of an active open question

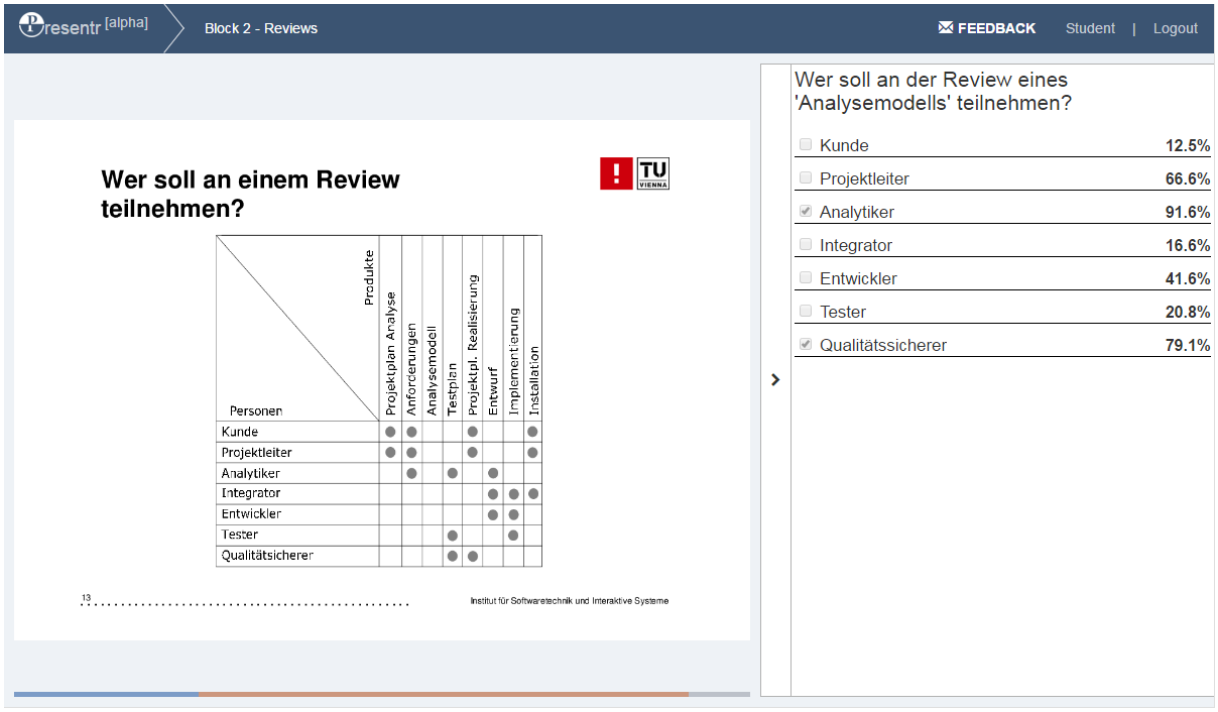


Figure 16: Prototype screenshot, student view of an finished survey

5.4. Pilot test

The prototype was tested during the lecture “Software Engineering and Project Management” (SEPM) in the summer term 2015. This course is a compulsory subject in each bachelor informatics study and is scheduled for the fourth semester in the study plan. Presentr had been deployed in 7 lecture units of SEPM, held by 4 different lecturers. The deployments occur from March to May 2015. While approximately 200 students were enrolled in the course SEPM, only about the half is attending during the lecture units.

The 4 lecturers got an introduction into Presentr before the lectures. The functions and capabilities of the tool were presented. Additionally the possible interactive tasks that could be conducted were discussed.

To gather feedback from the deployments different methods were used. First the lecturers were observed during each lecture. The investigation focused on items like how Presentr is introduced, how the students were invited or how an interactive task is conducted. Second the students were observed while using Presentr. During observation the focus was on their use/non-use of Presentr, problems of students while using the tool, participation of the students in interactive tasks. Third the students and lecturers were invited to give personal feedback on Presentr after the lecture units. Finally a feedback function was implemented directly into the client were the students have the possibility to give written feedback about the tool.

Observations

During the interactive task type open question some students had given answers that were not related to the question. Answers like questioning about course organization, discuss the presentation style of the lecturer or test the system against SQL injection vulnerability were provided. According to the lecturers and some of the students the main problem is the anonymity of the system. It provokes unrelated answers because the authors cannot be made responsible for their contributions. The system should therefore identify the students, but it was mentioned that as an option the students can still provide their answers anonymously. As a possible mitigation solution it was suggested that the lecturer can hide single answers from the students.

During the seven lecture units the performance of the prototype was investigated. The maximum number of concurrent students using the system was 82. During the session with 82 students the distribution of lecture events, like slide changes or start of an interactive task worked without any noticeable latency. Furthermore the contributions of the students, like voting for an answer option or adding a new answer, worked like expected. A problem emerged, when more than 50 students used the system simultaneously, a delay in the delivery of the web client occurred. Under these circumstances the initial load of the webpage had a delay of approximately 2-3 seconds.

Another technical problem was the delivery of the PDF files. In one lecture unit the lecturer used a PDF presentation that relies heavily on images with a PDF file size of 22 megabytes. During the upload and preparation process of the lecturer no problem with the file size occurred. But the distribution of the PDF file to the clients of the students was problematic. After the start of the lecture, the students got invited by the lecturer to follow the presentation with Presentr. Approximately 50 students accepted the invitation and browsed to Presentr. Because it wasn’t the

first lecture unit of the course most of the students were already logged-in and therefore were forwarded directly to the view were the presentation is displayed. For downloading the PDF file from the server a function that is built into PDF.js, which is the utilized PDF viewer library, were used. The default behavior of PDF.js is to spawn 5 simultaneous connections to the server with the aim to download the PDF file faster. Therefore 50 students had spawned in sum approximately 250 connections all trying to download a 22 megabyte large PDF file. While the uplink connection of our server handled it without problems, the WLAN infrastructure of the lecture room struggled with this task. The WLAN router or some component linked to the router was overwhelmed by the number of connections or the data volume that should be transferred. The router had been stalled and reset itself, resulting in a 5 minutes outage of the WLAN connectivity in the lecture room.

Feedback from lecturers

The lecturers noted that it would be beneficial if they could structure their presentations into the different courses they are holding. It would be easier to overview and prepare the presentations if they could be grouped by lecture courses. It was also mentioned that the students should see all presentations of one course at one place.

After conducting an interactive task the lecturer often discussed the results with the students, during that discussion he/she had to remain at the laptop to see the results and could not show the students which answer is currently discussed. It was suggested that the results should be displayed on the projector device, so that everybody can see the base of the discussion.

Two lecturers had a suggestion for the interactive task type open question. After the students had provided the answers it would be interesting to let them vote the answers of other students. This would be beneficial if there are many answers (i.e. more than 30), to apply some sort of ranking or order to the question. After the voting only the best or worst voted answers would be discussed.

The lecturers suggested a hint and auto start function for the interactive tasks. Most of the interactive tasks were scheduled at a specific point of the lecture at a specific slide of the presentation. It would be beneficial that the lecturer can specify a slide during the preparation of the interactive tasks. When holding the lecture the system should hint the lecturer that an interactive task should be started now. One lecturer even stated that he would use an auto start function where the interactive task starts on a specific slide automatically.

Two lecturers are normally using a presenter device to control their presentation slides and to point with the built-in laser pointer to specific areas of a presentation slide. The benefit for them is to be independent from the position of their laptop and can move around the lecture class as they like. Therefore they suggested that Presentr should support such presenter devices.

The lecturers suggested a function to re-upload the provided PDF file with a new one. The motivation of this re-upload process can be a discovered mistake or typo in the presentation slides, adding new slides to the presentation, remove slides from the presentation or move the order of the slides. During this process already prepared interactive tasks should be preserved.

Feedback from students

Through the feedback function of Presentr and through personal feedback of the students after the lecture units the students stated that not all functions of the applications are working on their smartphones. Depending on the smartphone, the operating system and used web browser some functions had worked, while others did not. The observations during the lecture have shown that approximately one third of the students tried to use their smartphone to participate with Presentr.

The students stated that they wanted to view the results of the interactive tasks after the lecture. Additionally some students would favor to be able to download the presentation slides directly from Presentr. Therefore options for export and download the results of interactive tasks for the students for the next iteration of Presentr were investigated.

6. Improved Prototype Development and Evaluation

After the pilot test was conducted, including the observations of the lecturers, the students and the collected feedback, the new insights were used to improve our first integrated Audience Response System prototype. For the improved prototype, a case study, were deployed. It spanned over multiple university courses, to evaluate the improved integrated Audience Response System tool.

6.1. Improved Requirements

The feedback from the pilot test were evaluated, emerging new requirements for the improved integrated Audience Response System prototype were discussed. Another brainstorm session [Clark, 1989] was conducted, discussing which feedback will be resulting in additional requirements, which requirements are taken from literature in addition and which other requirements are needed for the first prototype. The requirements listed from table 18a to table 18e have been emerged after the brainstorm session. The requirements are marked whether they are inherit from the first prototype, have references to requirements from the literature or where emerging as new requirements from the pilot test. Text passages enclosed by brackets indicate changes or additions to requirements from the first prototype or literature. The requirements are described in detail below.

Technical requirements

The students can answer anonymously, if the lecturer allows it. With the introduction of the Vienna University of Technology's single-sign-on the lecturer has the option for the interactive task type open question, if the students are stated by their name or remain anonymously.

The webpage, for the students, where they can find the presentations and participate in interactive tasks, has a short URL, which is easy to remember and defined by the lecturer. With this requirement the lecturers can self-define a short URL for their presentation portals, like the abbreviation for their course. This is an improvement compared to the first prototype, where the URL was predefined by the system.

The system supports multiple device classes (laptop, tablet and smartphones). In addition to laptop and tablet devices, smartphone should be supported, due to their high distribution as shown in the pilot test. If the device has insufficient capabilities for all functionality of the system, it should at least enable the smartphone user to participate in interactive tasks.

The system supports at least 200 students, using the system concurrently. With double the goal of the initial prototype the architecture and technology stack should be prepared for deployment in larger lecture classes.

The system supports the log-in via the university's single-sign-on for lecturers and students. This item lowers the entry barrier for lecturers and students, because they can use their existing university account for the system. They do not need to create an additional account or remember another password. Additionally the students should recognize that the system has identified them personally, hopefully preventing the students from providing unrelated answers.

The system delivers the lecturer presentation slides to the audience clients as single images. As consequence of the pilot tests the system generates one image per slide out of the uploaded presentation slides. The images are distributed to the lecturer clients when needed.

Technical requirements	From first prototype	New from literature	New from pilot test
The system supports internationalization and is localized in English and German.	X		
The system distributes lecture actions and students answers with low latency.	X		
The students can answer anonymously, [if the lecturer allows it].	X		X
The webpage, for the students, where they can find the presentations and participate in interactive tasks, has a short URL, which is easy to remember [and defined by the lecturer].	X		X
The system supports multiple device classes (laptop, tablet [and smartphones]).	X		X
The system supports at least [200] students, using the system concurrently.	X		X
The system supports the log-in via the university's single-sign-on for lecturers and students.			X
The system delivers the lecturer presentation slides to the audience clients as single images.			X

Table 18a: Technical requirements for the improved prototype

Interactive task type requirements

The lecturer can prepare quizzes to assess the students with single and multiple choice questions. The third most mentioned interactive task type of table 10 will be implemented into the system.

The lecturer can allow voting within the interactive task open question, where the students can up- or down-vote given answers from other colleagues. Designed as extension for the open question interactive task, the voting should help to identify valuable contributions, rank the given answers and keep the overview when a large amount of answers are given.

Interactive task type requirements	From first prototype	New from literature	New from pilot test
The lecturer can prepare surveys to poll the students with single and multiple choice questions.	X		
The lecturer can prepare open questions to get short free typed answers from the students.	X		
The lecturer can prepare quizzes to assess the students with single and multiple choice questions.		X	
The lecturer can allow voting within the interactive task open question, where the students can up- or down-vote given answers from other colleagues.			X

Table 18b: Interactive task type requirements for the improved prototype

Interactive task requirements

The lecturer can choose whether to show results during the interactive task or only when the task has been finished. Depending on the question of the interactive task the lecturer can prohibit or permit that students are influenced by already given answers from other students.

After the interactive task is finished, the lecturer can continue the task. This allows the lecturer to re-open accidentally finished interactive tasks or gives the lecturer the opportunity to invite more students in participating in an interactive task.

The results of the interactive task survey and quiz are visualized as bar chart. Additionally to the absolute numbers and percentages the result is visualized as bar chart for a better visualization of the proportions.

In the interactive task open question, single answers from the students can be hidden from the results, as suggested by the lecturers during the pilot test.

The lecturer can assign each interactive task a presentation slide; the system displays a hint to start the interactive task if the specified slide is reached during the lecture. This is giving the lecturer additional support during the lecture with reminding him/her that an interactive task should be conducted.

The lecturer can assign each interactive task a presentation slide; the system starts the interactive task automatically if the specified slide is reached during the lecture. For lecturers that precisely plan their presentations, this function gives them the ability to start interactive tasks automatically.

The lecturer can reset interactive tasks and start them again from the initial state. This function enables the lecturer to reset and re-start an interactive task that was unintentionally started too early.

Interactive task requirements	From first prototype	New from literature	New from pilot test
The lecturer can start and stop the interactive tasks.	X		
The lecturer can pose multiple interactive tasks during the same lecture.	X		
The results of the interactive task survey show the number and percent of votes for each answer item.	X		
The lecturer can prepare interactive tasks for a lecture.	X		
The lecturer can choose whether to show results during the interactive task or only when the task has finished.		X	
After the interactive task is finished, the lecturer can re-continue the task.		X	
The results of the interactive task survey and quiz are visualized as bar chart.		X	
In the interactive task open question, single answers from the students can be hidden from the results.			X
The lecturer can assign each interactive task a presentation slide; the system displays a hint to start the interactive task if the specified slide is reached during the lecture.			X
The lecturer can assign each interactive task a presentation slide; the system starts the interactive task automatically if the specified slide is reached during the lecture.			X
The lecturer can reset interactive tasks and start them again from the initial state.			X

Table 18c: Interactive task requirements for the improved prototype

Presentation slides requirements

The lecturer can use multiple views for presentation projection and controlling the interactive tasks simultaneously. This is giving the lecturer the freedom to use multiple devices for controlling the presentation and supporting lectures where the audience is split into two or more lecture rooms.

The lecturer can navigate through the slides by using a keyboard, on screen control buttons or a presenter device. Supporting presenter devices was requested during the pilot test.

After an interactive task, the lecturer may either hide the result overlay by clicking a toggle and return to the current slide, or advance to the next slide. This should simplify the continuing of the presentation after the results of an interactive task were discussed. The lecturer can simply change to the next slide of his/her presentation and the result overlay will be hidden.

The URL, which enables the students to join the presentation, is displayed on the projector view; it is visible for the first slides of the presentation and when an interactive task is active. To provide the students with their entry point to the system, the required URL will be displayed at the top or the bottom of the presentation as overlay. The overlay will be displayed at the first 5 slides and while an interactive task is active, allowing students that attend the course later to join the interactive lecture.

The lecturer can re-upload PDF files of presentations without losing already defined interactive tasks. As requested during the pilot test, the lecturer would like to have the possibility to upload a PDF file again and therefore replace the previously uploaded PDF file. The motivation of this re-upload process can be for example a discovered mistake or typo in the presentation slides, the wish to add new slides to the presentation, to remove slides from the presentation or to move the order of the slides.

The lecturer can arrange multiple presentations in presentation portals, which can represent a whole university course. As suggested by the lecturers the system should have the ability to represent a whole lecture course during one semester.

The lecturer can set the visibility of a presentation portal to public or private. In accordance with the function of the first prototype to set presentations either public or private, this visibility options should be migrated to the presentation portal.

Presentation slides requirements	From first prototype	New from literature	New from pilot test
The lecturers can upload their presentation slides as PDF files.	X		
Once connected to a presentation, each student sees the currently displayed slide on their device.	X		
Students cannot advance forward past the currently displayed slide of the lecturer.	X		
The lecturer can use [multiple] views for presentation projection and controlling the interactive tasks simultaneously.	X		X
The lecturer can navigate through the slides by using a keyboard, on screen control buttons [or a presenter device].	X		X
After an interactive task, the lecturer may either hide the result overlay by clicking a toggle and return to the current slide, or advance to the next slide.		X	
The URL, which enables the students to join the presentation, is displayed on the projector view; it is visible for the first slides of the presentation [and when an interactive task is active].		X	X
The lecturer can re-upload PDF files of presentations, without losing already defined interactive tasks.			X
The lecturer can arrange multiple presentations in presentation portals, which can represent a whole university course.			X
The lecturer can set the visibility of a presentation portal to public or private.			X

Table 18d: Presentation slides requirements for the improved prototype

Post-processing requirements

The system supports a combined export, where presentation slides and the results of the interactive tasks are bundled into one PDF file for the lecturers and students. In addition to the existing CSV export a combined PDF export will be implemented. The combined export bundles the presentation slide of the lecturer with the results from the interactive tasks, which are visualized with charts where applicable.

The students can view the presentation slides and the interactive task results after the lecture. This requirement enables the students to browse back to Presentr after the lecture and view the presentation slides and results of the interactive tasks again.

Post-processing requirements	From first prototype	New from literature	New from pilot test
The system supports downloading of the interactive task results as CSV files for the lecturers.	X		
The system supports a combined export, where presentation slides and the results of the interactive tasks are bundled into one PDF file, for the lecturers and students.			X
The students can view the presentation slides and the interactive task results after the lecture.			X

Table 18e: Post-processing requirements for the improved prototype

6.2. Improved prototype development

After the new requirements were defined, the development of the improved prototype started. The working title of the project is still "Presentr" and the logo remains the same as shown in figure 4.

Figure 4: Prototype logo

Architecture

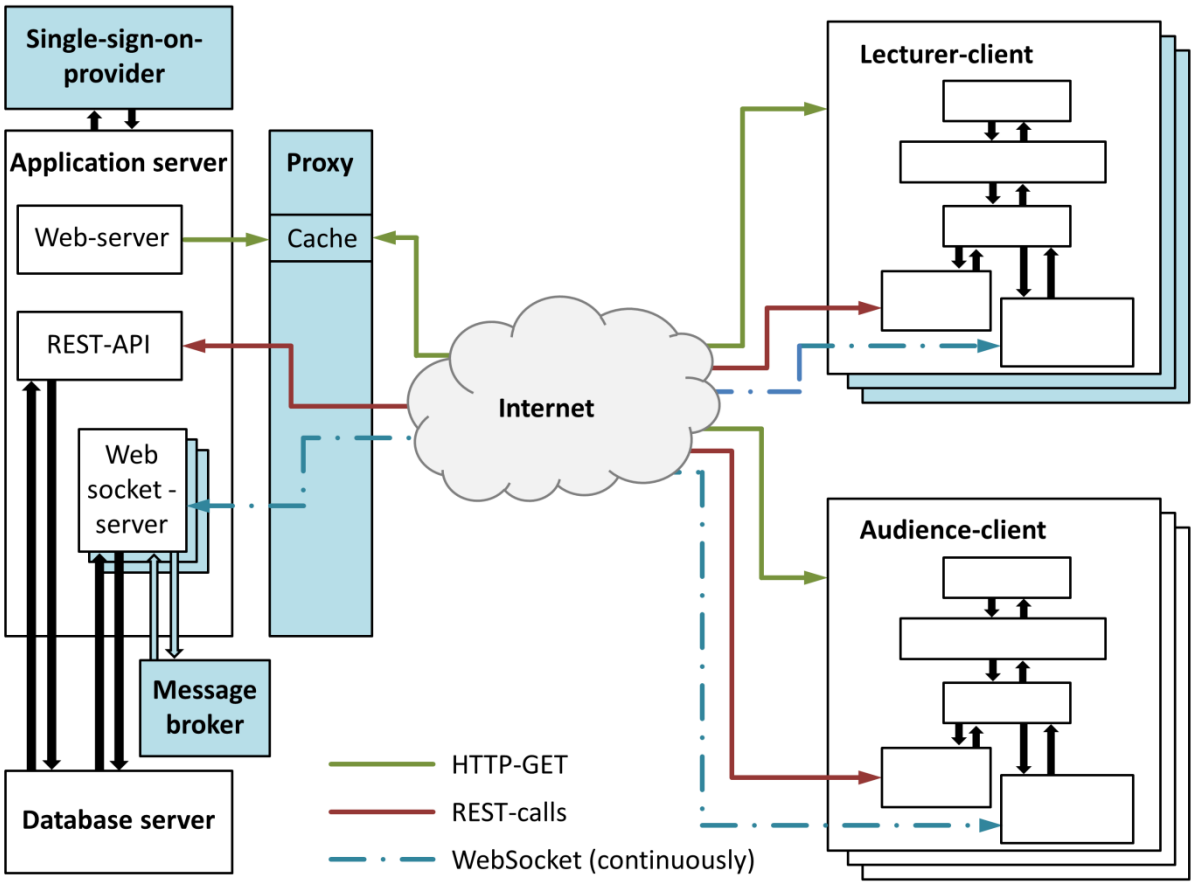


Figure 17: Improved prototype architecture

Figure 17 shows the architecture of the improved prototype differences to the architecture of the first prototype are color-coded. It was developed with the same methods as the architecture of the first prototype with a value-based approach cf. [Biffl, Aurum, Boehm, Erdogmus, & Grünbacher, 2006]. The improvements of the architecture address the following problems. The 2-3 seconds delay when loading the webpage while the system is under load (i.e. 50 students concurrently using the system). The system should be scalable even if the number of students rises by one magnitude. The students should be personally identifiable. The lecturer should be able to open multiple views for controlling the presentation slides and interactive tasks. Most of the architecture changes belong to the server part of the system.

First the single-sign-on provider from the university (in our case the single-sign-on service provider of the Vienna University of Technology) is connected to the server. This is mandatory to achieve the following login workflow. When the students log themselves in on Presentr, they are redirected to

the SSO provider. They provide their credentials from their university account and get redirected to Presentr. If the students are already logged in into a university application with their university account, they are redirected back to Presentr without the need of providing their credentials again. After the students logged in successfully at the SSO provider, the provider sends the authentication data to our server. The students are now logged in at Presentr with their university account.

To accelerate the initial load of the webpage at the browsers of the students, a proxy server is slotted in front of the application server. The proxy server caches the client code which is delivered to the web browsers. Due to our commitment for nearly real time communication and low latencies only the static parts of the client can be cached. Therefore all REST-API calls and WebSocket connections are tunneled unchanged through the proxy server to the application server.

During a lecture the real-time critical communication (e.g. change slide, start interactive task, add answer) of the lecturer and audience client with the server is realized through WebSocket connections. To remain scalable, the WebSocket server, which is a part of the application server, is prepared to support horizontal scaling. Therefore the WebSocket server can run with multiple instances on the same or on other distributed servers and balance the load of socket connections between the instances. In order that an event (e.g. a slide change) is broadcasted to all WebSocket clients a message broker is used that informs the all WebSocket servers in case of a broadcast event.

On the client side the projector view and the view for the laptop of the lecturer is adapted. It now supports multiple view instances that all show the presentation slides, in case of the projector view or that all let the lecturer control the presentation slides and the interactive tasks in case of the laptop view.

Technology stack

For the improved prototype the following technologies have been deployed additionally to the used technologies for the first prototype.

For the connection with the single-sign-on provider the authentication middleware passport.js[23] is used. It modularizes the authentication process with splitting it into authentication strategies. The SSO of Vienna University of technology was implemented as own authentication strategy. This preserves the flexibility to additionally provide the previously used username/password authentication method or implement other methods in future iterations.

As proxy server with integrated caching capabilities Nginx[24] is deployed. Nginx is a small, fast and reliable proxy server with a multitude of features. In the present project it's used as cache for the static parts of the client and as reverse proxy. Using a reverse proxy has the advantage that multiple separated instances of the application server run under the same public IP address but with different sub domains. For example a development system runs under the subdomain dev.presentr.at while the productive system remains on presentr.at.

[23] **passport.js.** http://passportjs.org
[24] **Nginx.** http://nginx.org

To support the delivery of the lecturer presentation slides as single images to the audience clients an external program called Ghostscript[25] was used. Ghostscript is a collection of software tools to handle PostScript[26] and PDF documents. Within the present system it is used to generate images out of each presentation slides PDF file. The images are generated in three different density resolutions providing the client the choice of finding the optimal tradeoff between size/loading time and resolution.

As stated in the architecture the WebSocket server is prepared to support horizontal scaling. To enable the broadcasting of events, like a slide change from a lecturer, across multiple servers the in-memory store Redis[27] is used as message broker. Redis enables the WebSocket server instances to communicate with each other and therefore enables cross instance broadcasting. Because Redis is in-memory data storage, it only adds a small amount of latency to the broadcasting process. Additionally it has useful build-in features like automatic horizontal partitioning or advanced high availability options.

[25] **Ghostscript.** http://www.ghostscript.com
[26] **PostScript.** http://partners.adobe.com/public/developer/en/ps/PLRM.pdf
[27] **Redis.** http://redis.io

Workflow

In contrast to the first prototype creating accounts for the lecturers is not needed, because they can use the new single-sign-on login of the system. The workflow of the improved prototype is shown in figure 18.

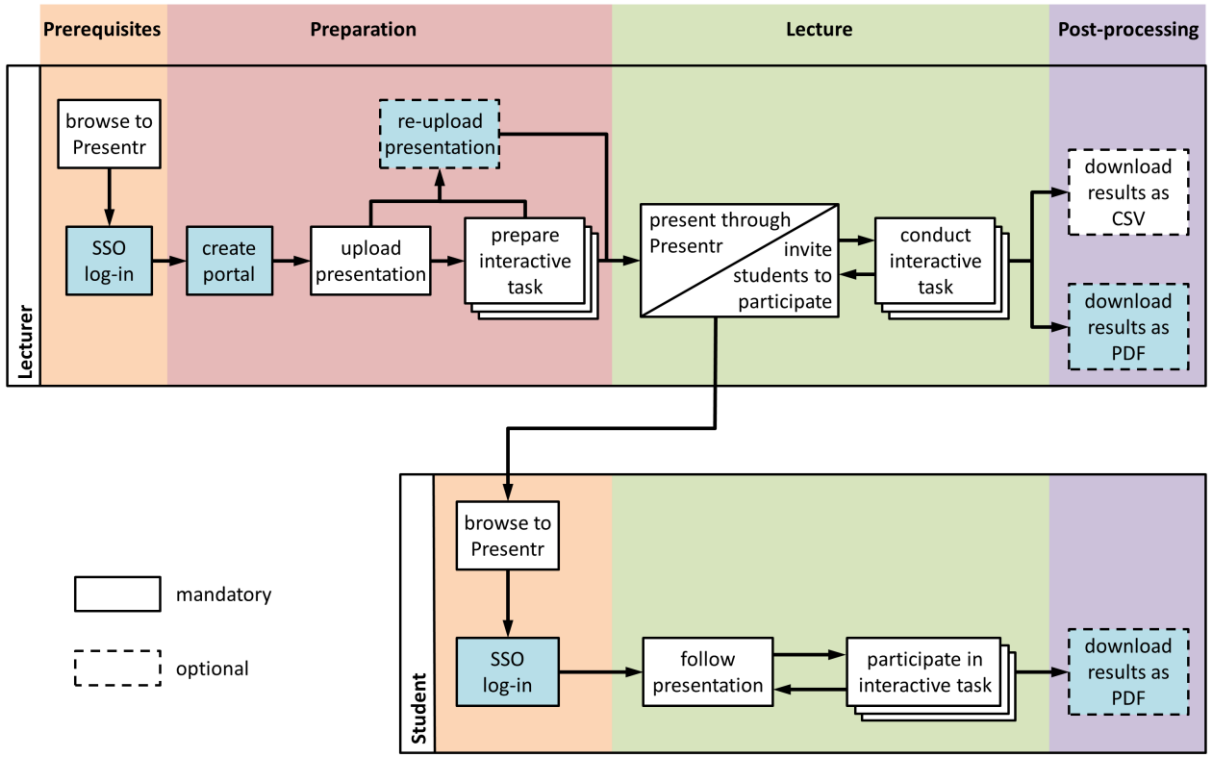


Figure 18: Improved prototype workflow

On the workflow of the lecturer the following changes to the first prototype emerged. After browsing to Presentr the lecturers log in with their university account via SSO. Before uploading a presentation the lecturers must create a presentation portal. If the lecturer modified his/her presentation slides before the lecture, he/she can re-upload the modified PDF file and exchange the old one. After the lecture it is also possible to download the results of the interactive tasks as CSV or PDF file.

The workflow of the students counts two differences to their workflow in the first prototype. First they do not register themselves with a self-chosen username and password, but rather log in with their student account via SSO. The second change is the optional possibility to download the results of the interactive tasks bundled with the presentation slides as PDF file.

Lecturer workflow

1. The lecturer browses to Presentr
2. The lecturer logs-in via SSO
3. The lecturer creates a presentation portal and defines a URL
4. The lecturer uploads his/her presentation slides as PDF file into the portal
   The lecturer can optionally re-upload a modified PDF file
5. The lecturer prepares the interactive tasks
6. The lecturer holds his/her lecture through Presentr and invites the students to participate through the automatically displayed URL
7. The lecturer uses the prepared interactive tasks during the lecture
8. The lecturer can optionally download the results of the interactive tasks as CSV or PDF file

After the lecturer logs himself/herself in he/she is forwarded to the overview of his/her presentation portals. The lecturer has the portal “How to Presentr”, which contains short tutorial presentations about Presentr, automatically assigned and can explore all tutorial presentations. Figure 19 shows the described initial portal overview of the lecturer. The lecturer can then add a new portal with a self-chosen name. The access level of the portal can be set to public, i.e. available for the students or private, i.e. only the lecturer can see the portal. Each newly created portal gets automatically a randomly generated short URL associated. The lecturer can change the short URL of the presentation portal to a self-chosen name, as long as the name is unique in the system. The lecturer can upload PDF files from his/her computer to Presentr either via the upload button or via the drag-and-drop function directly into a presentation portal. The presentations can be moved between different portals via drag-and-drop. Figure 20 shows a presentation portal with 3 uploaded presentations in it.

If the lecturer modifies his/her presentation slides before the lecture e.g. finds an error in his/her slides, adds additional content or changes the order of the slides, he/she can re-upload the modified PDF file to Presentr. The client uploads the new PDF file to the server, which analyses the re-uploaded PDF and compares it with the old PDF file. The server generates single images for every slide of the new PDF file. Then it compares the images of the old PDF with the ones from the new PDF. If the server detects that a slide has been moved it checks if the slide has any predefined interactive tasks associated. If yes, it moves the interactive tasks to the right position. If the slide count of the old and new PDF is different, the server checks that no interactive task is prepared on a slide that does not exist in the new PDF file. After the image generation and checks the server informs the client that the re-upload process was completed successfully.

During the preparation of an interactive task the lecturer can optionally define a specific slide of the presentation, where the system hints the lecturer to start or automatically start the interactive task. Figure 21 shows the creation of an interactive task of the type quiz. New options in contrast to the first prototype are the option to allow students to vote the answers of other students and define a slide where the system hints the lecturer to start or automatically starts the interactive task.

In respect to the pilot test, the result view of the interactive task type open question has been improved. It now uses more space for displaying more answers of the students, supply a sorting function of the answers in respect to the given votes and provides the possibility to hide single answers from the students. Figure 22 shows the improved result view.

Figure 23 represents the new method for inviting students to Presentr. The short URL, predefined by the lecture, is displayed at the projector view which is displayed by the projector device (e.g. a beamer). The URL is displayed during the first ten slides and while an interactive task is active. If the position of the toolbar where the URL is displayed overlaps important content of the presentation slides it can be moved to the top of the webpage.

To illustrate the result view on the projector device with the new implemented bar chart, figure 24 shows the result of a multiple choice interactive task. The size of the presentation slides and the result view is automatically adapted to the resolution of the projector device.

To produce the following screenshots the presentation slides were provided by Stefan Biffl and Dietmar Winkler from the course “Software Qualitätssicherung”[28] (software quality management).

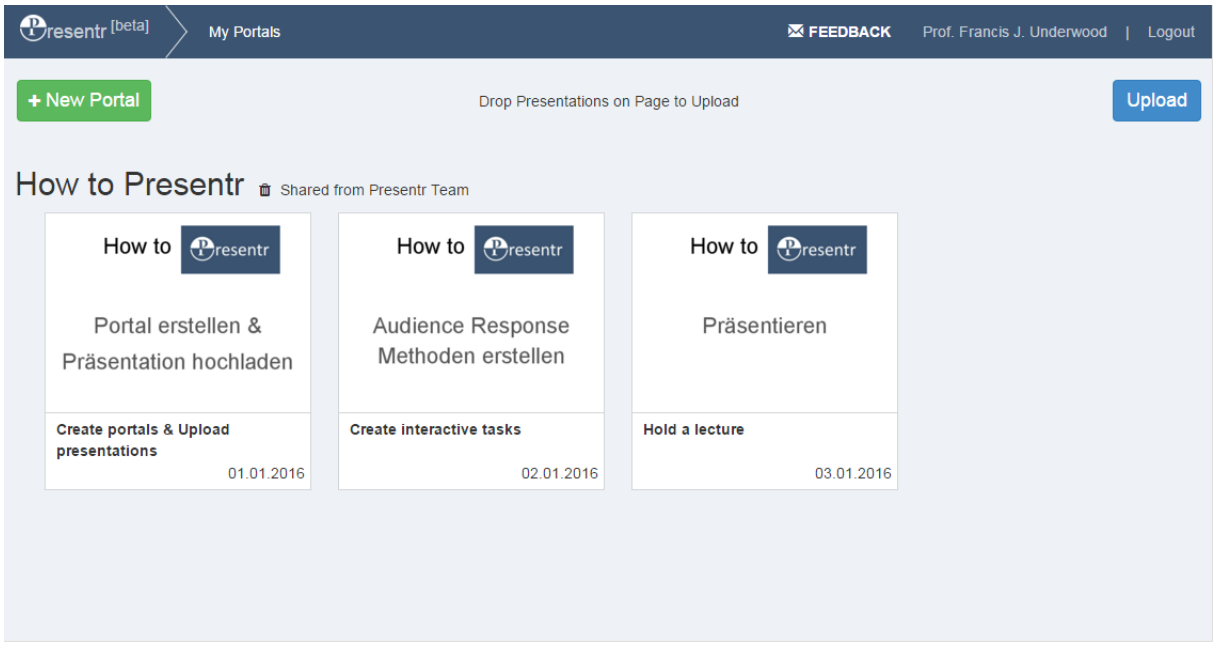


Figure 19: Improved prototype screenshot, initial portal overview

[28] **Software Qualitätssicherung.** https://tuwel.tuwien.ac.at/course/view.php?id=6958

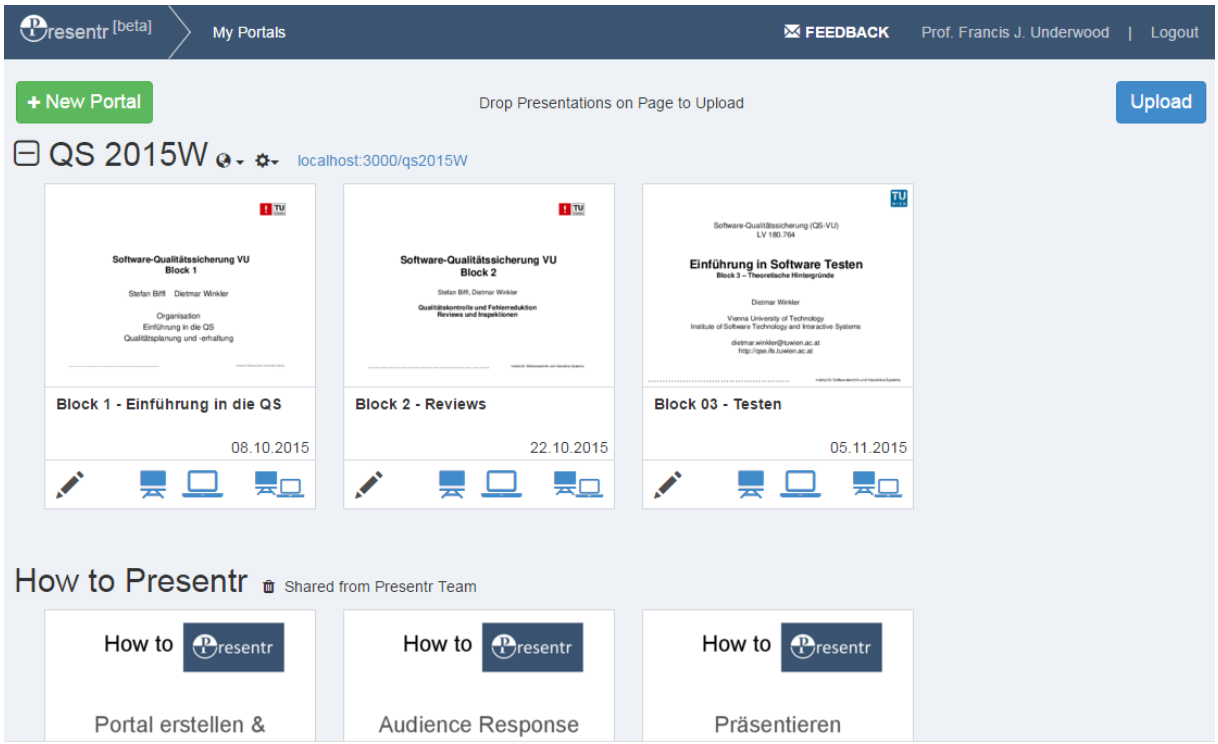


Figure 20: Improved prototype screenshot, portal overview with presentation portal

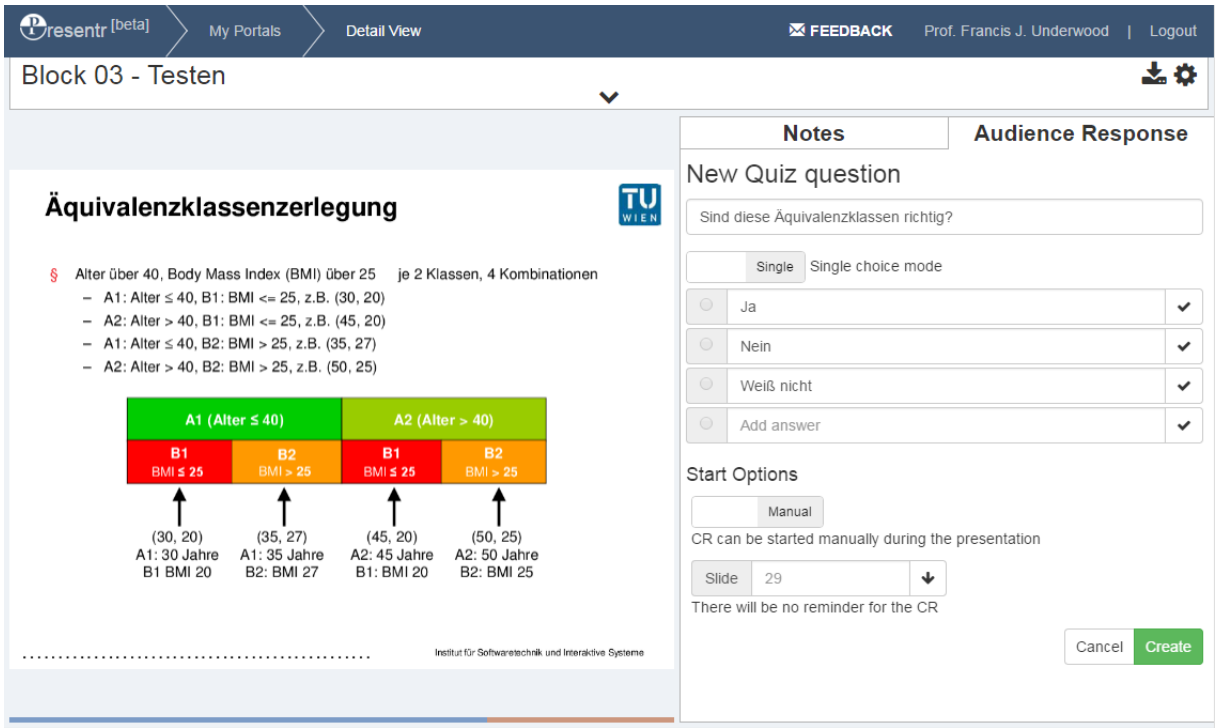


Figure 21: Improved prototype screenshot, preparation of quiz

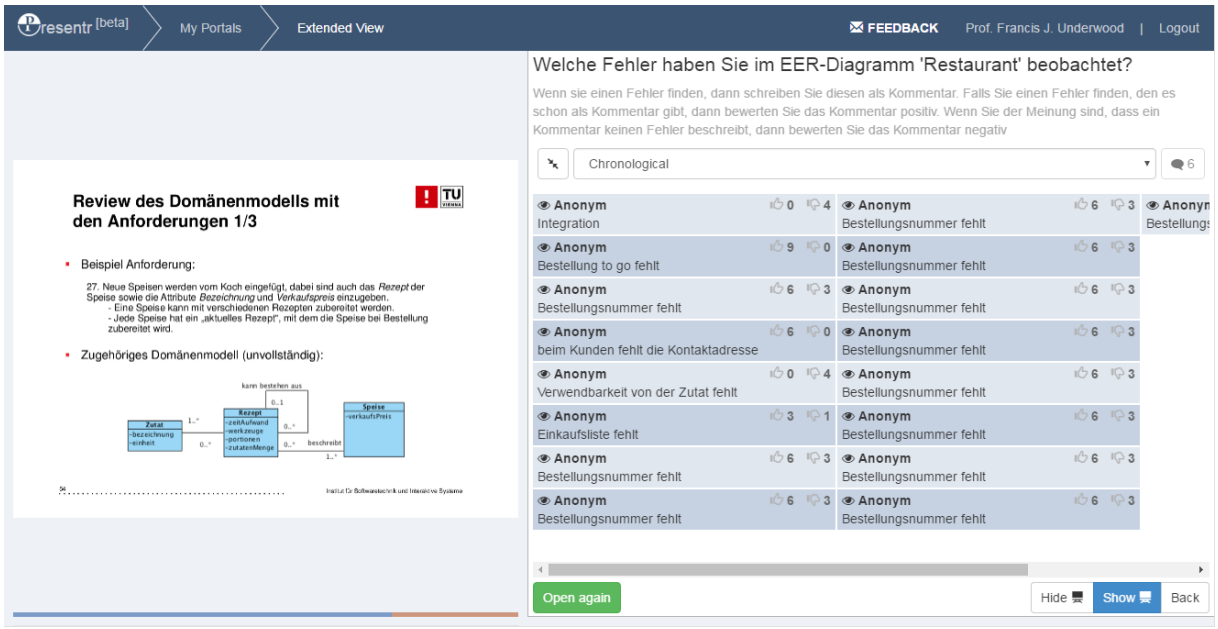


Figure 22: Improved prototype screenshot, improved results of open question

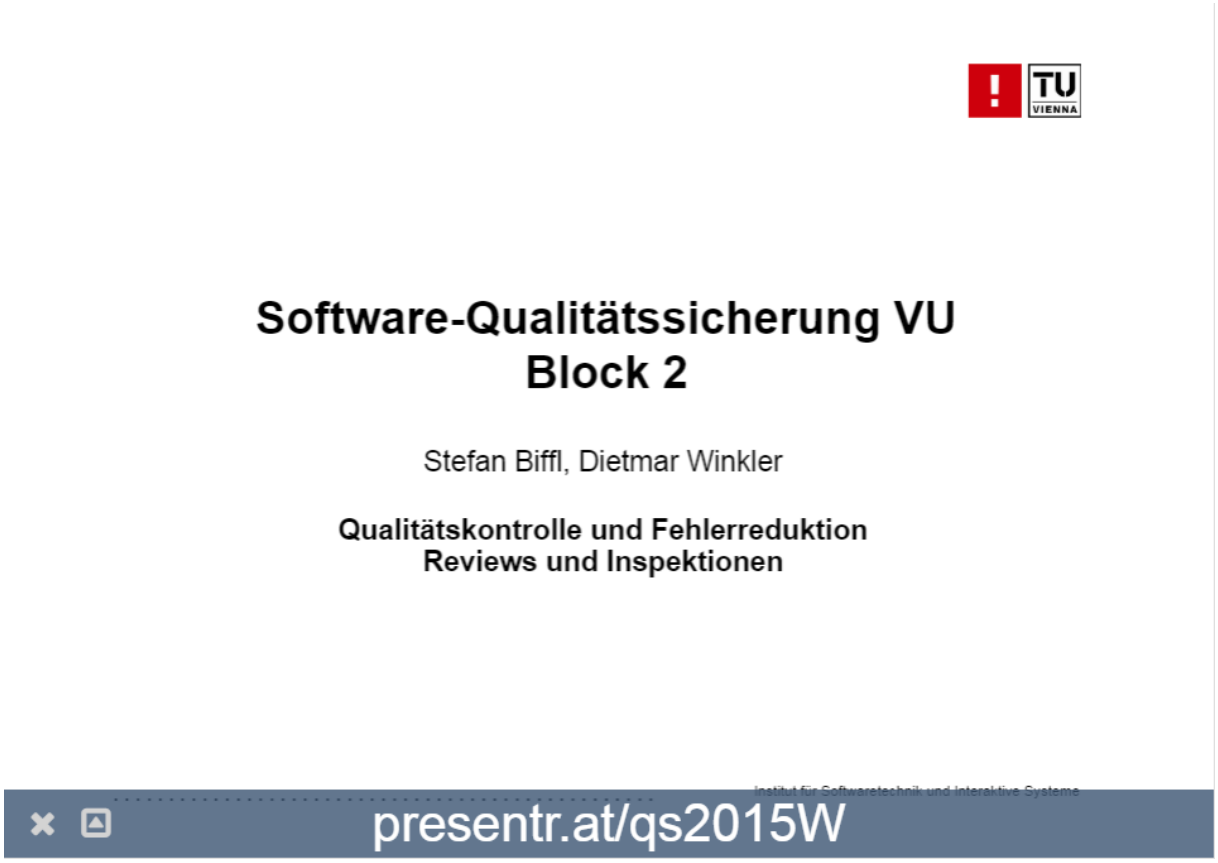


Figure 23: Improved prototype screenshot, projector view with short URL

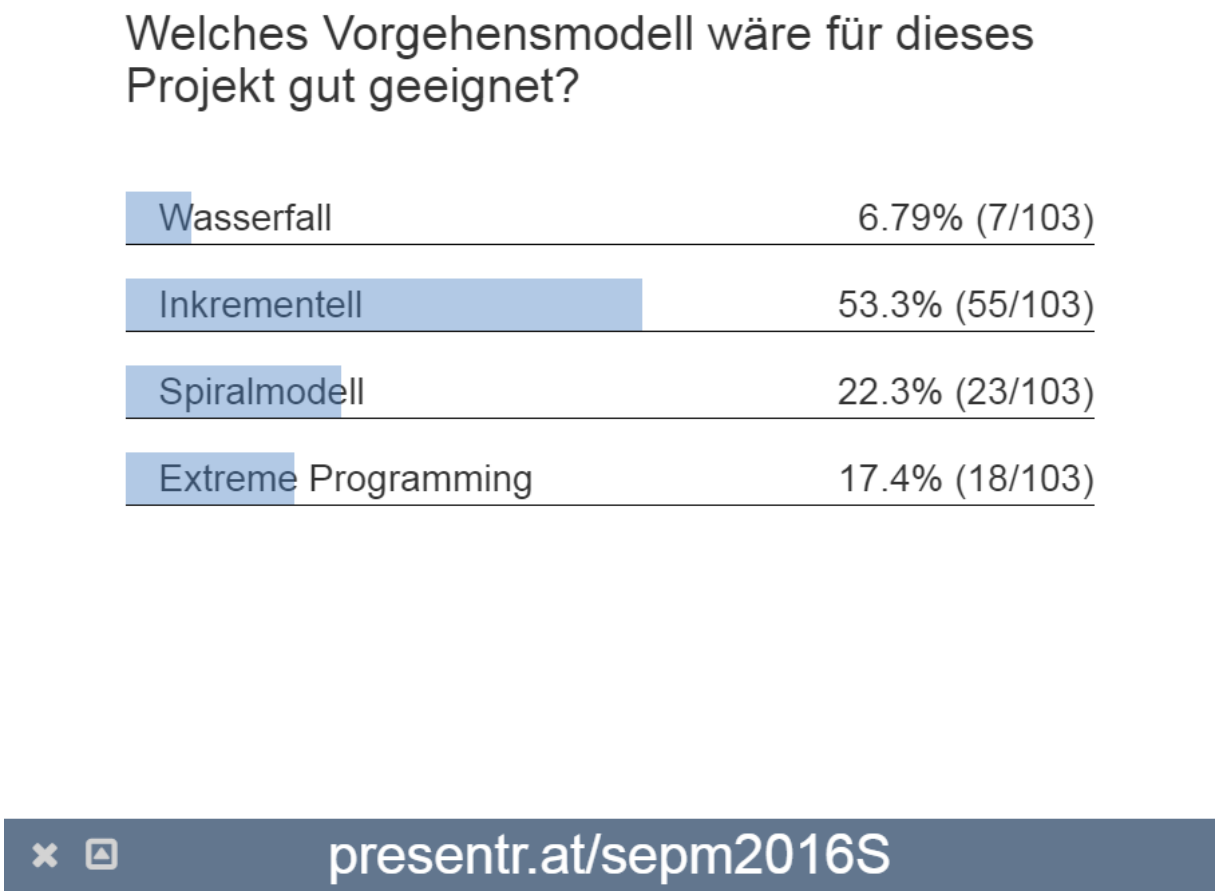


Figure 24: Improved prototype screenshot, projector view with survey results

Student workflow

1. The student browses to the URL displayed from the system
2. The student logs-in via SSO
3. The student follows the presentation
4. The student participates in interactive tasks
5. The student can optionally download the presentation slide with or without the results of the interactive tasks as PDF file

After the student follows the short URL as presented on the projector view by the lecturer, he/she is redirected to the presentation portal of the lecturer. In the portal all presentations, which were added by the lecturer, are listed. If a presentation is currently active, i.e. the lecturer is currently holding a lecture; the specific presentation is marked with a play symbol. Figure 25 shows a presentation portal with 3 presentations, from which one is currently active.

As the pilot test had shown a high distribution of smartphones at the students, Presentr has been improved to allow students to participate on interactive tasks with a smartphone. Figure 27 shows the view of a student with a smartphone browser, while an interactive task type survey is active but has not been answered yet by the student.

In the first prototype the students could follow the lecture via Presentr; but after the lecture had been finished, they had no possibility to export the presentation slides or the results of the interactive task to their devices. With the improved prototype the system provides an export function for the students. Figure 26 represents the export modal dialog for the students figure 28 shows an example of the newly implemented bundled export. In the bundled export the presentation slides of the lecturer and the results of the interactive tasks get combined into one PDF file. This allows the students to export all relevant data of the lecture session into one PDF file and have one source of learning material.

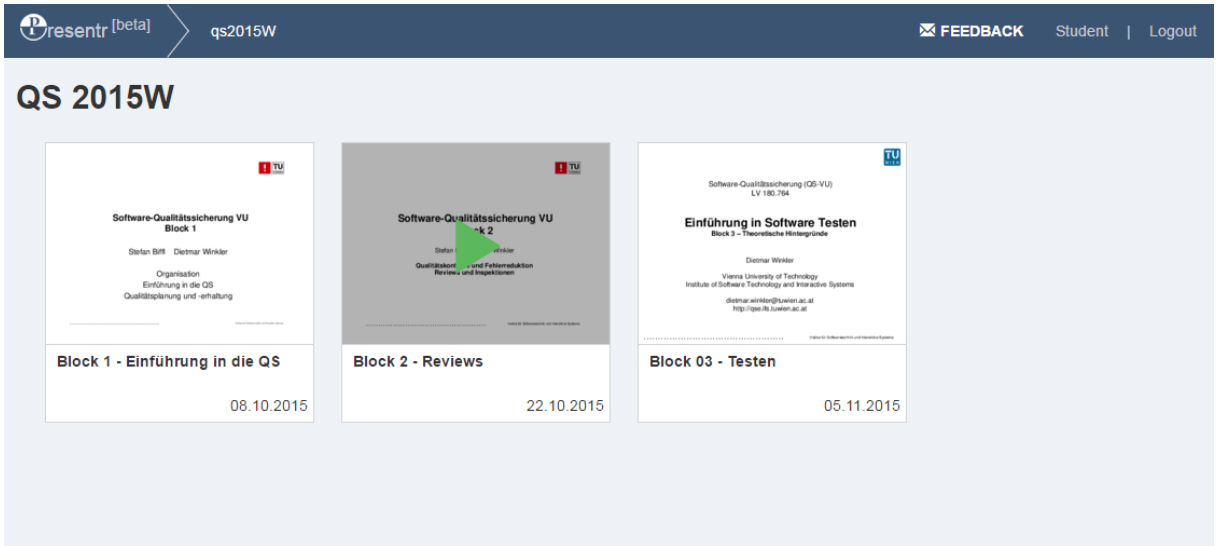


Figure 25: Improved prototype screenshot, student view of portal

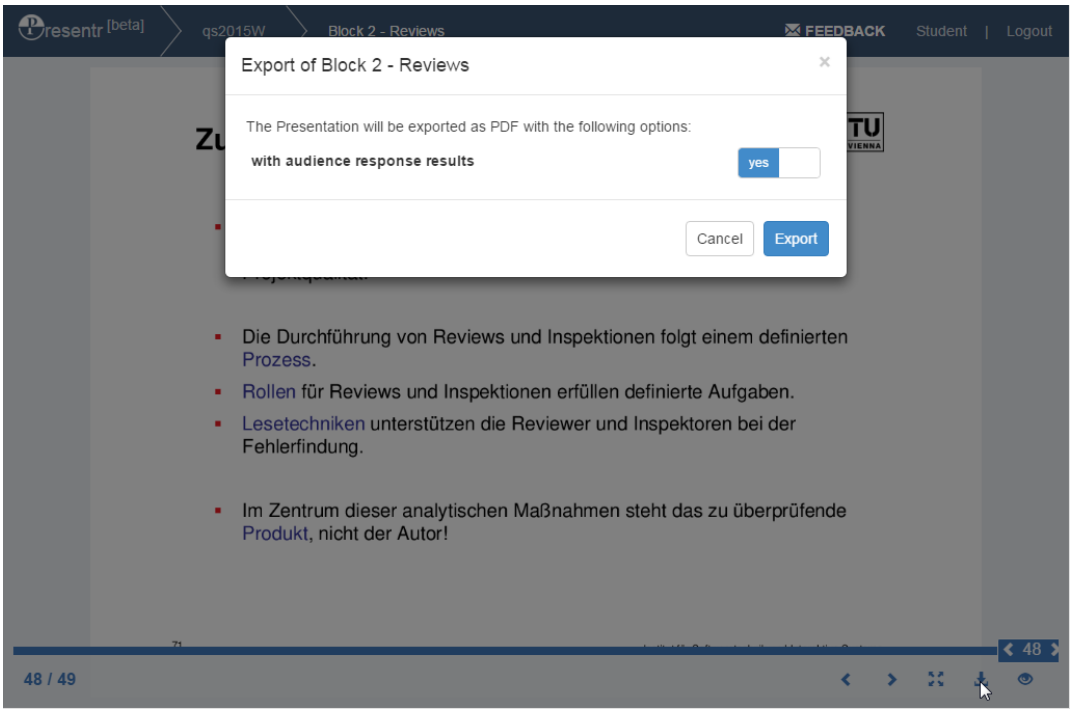


Figure 26: Improved prototype screenshot, student view of export modal

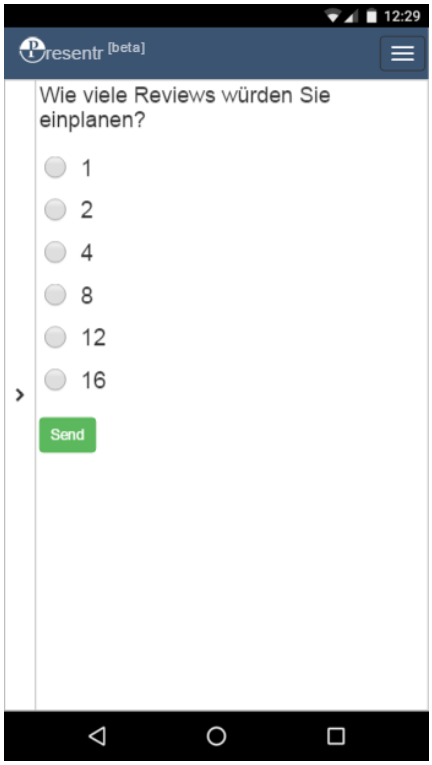


Figure 27: Improved prototype screenshot, mobile student view of an active survey

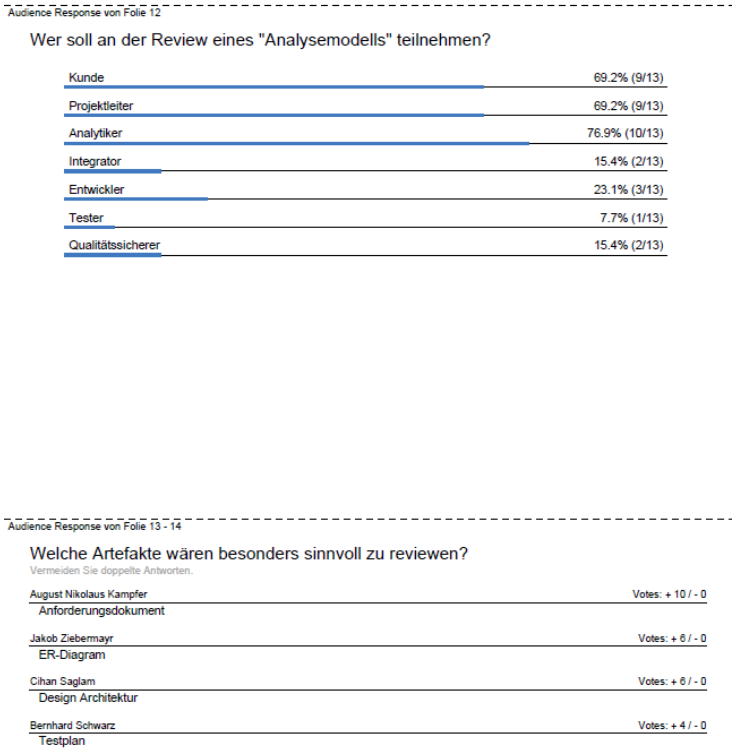


Figure 28: Improved prototype screenshot, excerpt from an exported presentation

6.3. Case study

The improved prototype was evaluated during multiple lectures, during the winter term 2015 and in the beginning of the summer term 2016 (only March). The design of the case study was oriented on the recommendations given in “Guidelines for conducting and reporting case study research in software engineering” [Runeson & Höst, 2009]. The deployed type of the study was an embedded case study, where multiple units of analysis are studied within a case cf. “Case study research: Design and methods” [Yin, 2013]. Each deployment of Presentr during a single lecture represents a single unit of analysis in the overall case study.

The lecturers who declared their will to use the audience response tool got an introduction into Presentr before their lectures. The functions and capabilities of the tool were presented and explained. The interactive tasks that were conducted during their lectures were not discussed, but rather were chosen solely by the lecturers.

To evaluate the tool different evaluation methods were conducted. First qualitative data was gathered by observing the lecturers and students during the deployment of Presentr in the lectures. Second the students and lecturers were invited to give personal feedback on Presentr after the lecture units. Third a feedback function was implemented directly into the client were the students have the possibility to give written feedback about the tool. Additionally as fourth evaluation method quantitative data was collected by surveying the students of the lectures with paper questionnaires, after the deployment of Presentr. The details of this survey are described in chapter 6.4.

Table 19 lists in which lectures Presentr was deployed, the term of the lecture, in how much of the lecture units it was used and from how much students a questionnaire was returned. In total 248 paper questionnaires had been filled out, returned and were evaluated.

Lectures	Term	Units used	Questionnaire responses
Software quality management	2015W	3	28
Requirements engineering and specification	2015W	5	40
Software engineering and project management	2016S	2	87
Software quality management	2016S	2	33
Introduction to scientific theory	2016S	2	60

Table 19: List of lectures where Presentr was deployed

Observations

During the lectures the performance of the improved prototype was monitored. The lecture the most students attended was a lecture unit of “Introduction to Scientific Theory” with over 200 students in the lecture room. 140 students followed the lecture and participated in interactive tasks through Presentr. During the lecture there was no noticeable latency during the distribution of lecture events, like slide changes or start of an interactive task. Additionally the problem of the first prototype of having a delay in the delivery of the web client, when more than 50 students used the system simultaneously, was completely mitigated. The server delivered the audience clients fast, regardless of the concurrently connected clients. The server load did not exceed 20% of its capacity during the whole lecture. The server, in its current hardware configuration, could concurrently handle up to 500 students simultaneously, based on a conservative estimation.

In the first prototype the delivery of the whole PDF files to multiple clients was problematic for the WLAN infrastructure of the university. To mitigate this problem the improved prototype provides the presentation slides as single images. The delivery of single images over the WLAN infrastructure worked well; there were no network outages or noticeable delays.

The problem of the first prototype, that students were giving unrelated answers within the interactive task type open question has been successfully mitigated with the introduction of Single-Sign-On. The students were aware that the system knows their identity and answered with statements related to the provided question. Even if the interactive task was set to anonymous answers, where the students and the lecturers did not know who had given a specific answer, the number of unrelated answers was very low. If the students gave unrelated answers, which happened only occasionally, the answer was hidden by the lecturer with the answer hide function of the improved prototype.

In one lecture unit of “Software quality management” the built-in projector device of the lecture room was broken. The lecturer stated that he normally would cancel the lecture and shift it to another date, because his lecture highly relies on his presentation slides. As he deployed Presentr on his lecture, he wrote the URL for the students on the blackboard and invites the students to follow his presentation through Presentr. The audience client of the students automatically follows the slide controls of the lecturer and the whole lecture unit had been held successfully.

Feedback from lecturers

Three lecturers were conducting longer interactive tasks, where the students for example had to solve a calculation, find errors in the diagram of a model or state a solution for a given problem. To continue with the lecture according to the schedule of the lecture unit, each interactive task had to be solved in a given time limit. After the start of the interactive task one lecturer noted the remaining time on the blackboard, while the other two set an alarm on their mobile phones. During the waiting time the lecturers suggested that it would be beneficial if they could define a time limit at each interactive task, which is then showed on the projector device for the students.

During the preparation of their lectures with Presentr, two lecturers asked if it is possible to set specific presentations in a public presentation portal to private. They would then be able to prepare one or multiple presentations in advance, without the problem that the students can see the presentations which are still in their preparation phase.

One lecturer had split up the appearance animations of his presentation into multiple presentation slides. Therefore each presentation slide in the animation series represents one step of the appearance animation and therefore adds one additional element to the slide. The problem was that the split of the animation was resulting in 4 to 6 additional slides which only showed part of the information. If the students used the combined export and download the presentation slides they

got all presentation slides inclusive the ones that only show part of the information. Thus a function was proposed to group by presentation slides during the preparation of the presentation. If the students then use the combined export functionality, only the last slide of each slide group which shows the full information will be exported.

Most of the lecturers are using the Moodle[29] system of the university to manage their lecture courses and provide the students their presentation slides before and/or after the lecture. The use of Presentr adds an additional system, where the lecturers have to add their presentation slides. Additionally if they wanted to provide the combined export PDF at the Moodle course they had to download the combined export PDF from Presentr and upload it to their Moodle course. Therefore it was proposed to implement an interface between Presentr and the Moodle system of the university. Presentations that are uploaded to the Moodle system would then be automatically available at the Presentr system and after holding a lecture unit the combined export PDF would be automatically uploaded to the Moodle course of the lecturer.

Feedback from students

Several students questioned if they can write personal notes or comments to specific slides of the presentation or write a transcript during the whole lecture within Presentr. Therefore to combine both possibilities for the students, a transcript possibility with an integrated slide annotation function is proposed. The students could then write a transcript during the lecture and the system recognizes and saves which part of the transcript was written during which slide of the presentation. Additionally an export function for the resulting transcript is suggested to be implemented.

Two students suggested that they would like to add photos to a presentation and export them with the combined export function. The students stated that they currently are making pictures with their smartphones from written transcripts and drawn models on paper or information which is added by the lecturer on the blackboard. They suggested a function where the taken pictures from the smartphone can directly be uploaded to Presentr and get exported with the combined export at specific points in the presentation.

[29] **Moodle.** https://moodle.org/

6.4. Students survey

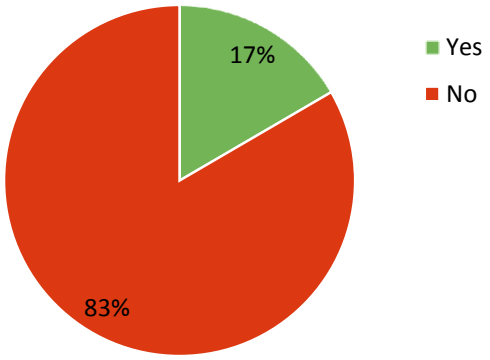
The survey was conducted by a one-page paper questionnaire which was handed-out at the end of the lecture. The students had to fill it out on site and returned it directly thereafter. The survey was designed after the "Preliminary Guidelines for Empirical Research in Software Engineering" [Kitchenham, et al., 2002]. The survey consisted of 11 questions, two yes/no questions, five 4-point-Likert-scale questions and four open questions. The questionnaire was conducted in German and an empty questionnaire sheet can be found in the appendix A2 of this thesis.

For the following descriptive results the questions of the questionnaire have been translated into English. Be aware that some of the German formulations cannot be translated exactly into English.

[1] Have you ever used a Classroom or Audience Response System, except Presentr, before this lecture?

Single-Choice Question

Answer options	**#**
Yes	41
No	206
Total answers	**247**



Before the answers of this question were evaluated the data has been cleaned. After this question an open question asked the students if they have used an ARS before, which one and in which lecture. If the students responded to this question with Presentr or a lecture, where only Presentr had been deployed, then their answer in this question has been changed to no.

17% of the students have already used an Audience Response System, besides Presentr. Out of the 41 students that used an ARS before 17 stated that they have used a system called "Aurora". Aurora is a custom build ARS tool which is deployed by one lecturer in two bachelor degree informatics lectures. 2 out of the 41 students stated that they have used the ARS tool named "Pingo"[30] before. Pingo is a publicly available tool from the University of Paderborn.

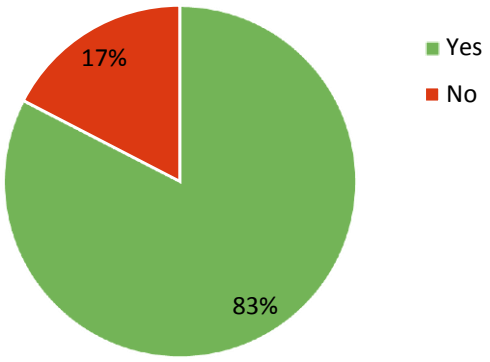
83% of the students never used an Audience Response System in a lecture before. This shows that the distribution of ARS systems at university lectures is currently very low and for most of the students the use of Presentr was their first contact with an Audience Response System.

[30] **Pingo.** https://pingo.upb.de

[2] Have you used Presentr today to answer questions from the lecturer?

Single-Choice Question

Answer options	#
Yes	204
No	43
Total answers	**247**



83% of the students have used Presentr during the lecture where the questionnaire was deployed. This high response rate from the students indicates a demand for an Audience Response System on the side of the students. Presentr provides a low entrance barrier as an ARS with more than 4 out of 5 students using it.

17% of the students have not used Presentr during the lecture where the questionnaire was deployed. A subsequent question asked the students why they haven't used Presentr during the lecture. Out of the 43 students that have not used Presentr 34 stated a reason why. The responses had been cleaned and grouped by similar topics. Table 20 shows the results of this evaluation.

Problem Groups	Occurrences	Relative occurrences
No device were available	12	35%
No motivation to participate	10	29%
Problems with smartphone compatibility	6	18%
Attended lecture after interactive tasks deployment	4	12%
Worked with a partner	2	6%

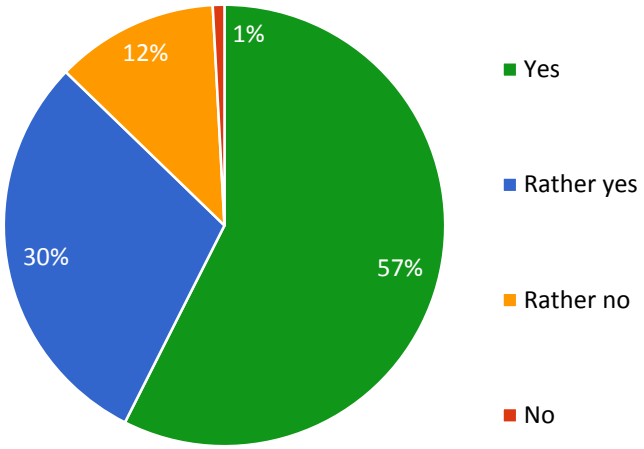
Table 20: Students Survey grouped problems

35% out of the 34 students had no digital device available to participate with Presentr. If the percentage of students with no devices is extrapolated to the surveyed population only 6% of the 247 students could not use the Audience Response System because they did not have an eligible device. 29% of the 34 students stated that they did not have the motivation to participate within the ARS. 6 out of 34 students had technical compatibility problems with Presentr on their smartphones.

[3] Do you find today's deployment of Presentr useful?

Single-Choice Question

Answer options	#
Yes	135
Rather yes	70
Rather no	28
No	2
Total answers	**235**



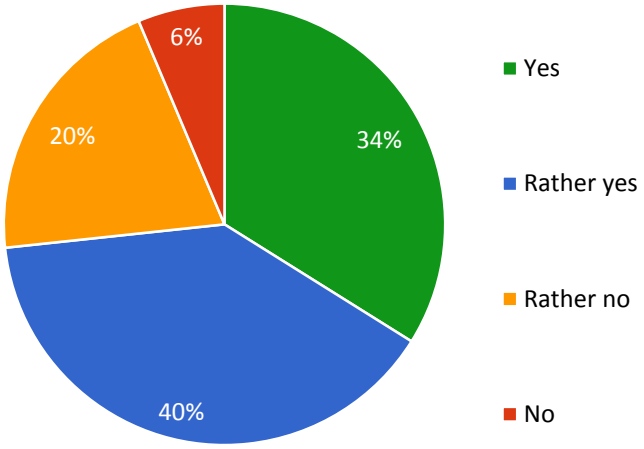
87% of the students have a positive attitude towards the usefulness of Presentr. 57% of the students are even convinced that their use of Presentr in the respective lecture was useful for them. These highly positive results further prove the demand for an Audience Response System on the side of the students.

13% of the students rate the usefulness of Presentr negatively, while only 1% of the students are convinced that the deployment of Presentr was not useful for them during the respective lecture.

[4] Would you agree to the statement that the deployment of Presentr was beneficial for understanding the lecture material?

Single-Choice Question

Answer options	#
Yes	80
Rather yes	93
Rather no	48
No	15
Total answers	**236**



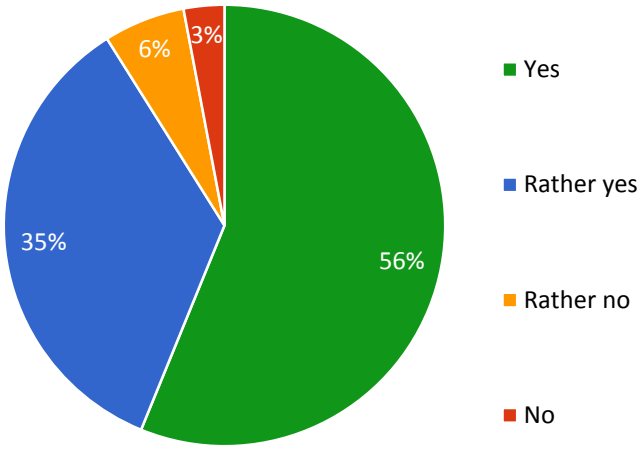
74% of the students say that the use of Presentr helped them to understand the content of the lecture. 34% are convinced that Presentr was beneficial for their understanding, 40% of the students see a positive influence. Therefore nearly 3 out of 4 students agree on the positive effect of Presentr.

26% of the students cannot agree that that Presentr was beneficial for their understanding of the lecture material. Only 6% say that Presentr had no positive effect on them regarding the understanding of the lecture material.

[5] Would you use Presentr again in other lectures?

Single-Choice Question

Answer options	#
Yes	132
Rather yes	82
Rather no	14
No	7
Total answers	**235**



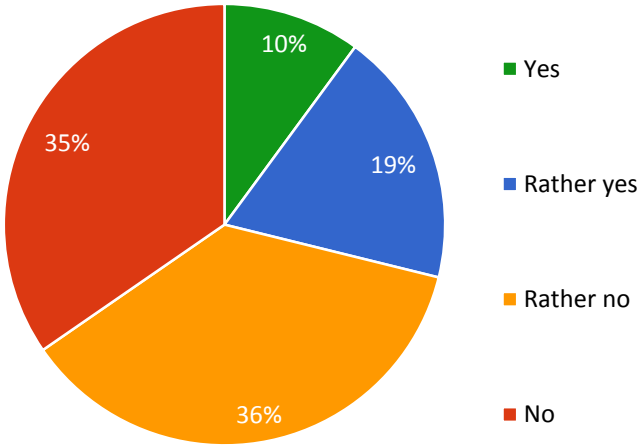
91% of the students would use Presentr again, if it is deployed in another lecture. This result shows a very high acceptance rate of Presentr and indicates that the system provides a low entrance barrier.

6% say that they would rather not use Presentr again in another lecture. Only 3% of the students are sure that they will not use Presentr again.

[6] Were you distracted from the lecture by using your device (laptop/tablet/smartphone) during the lecture?

Single-Choice Question

Answer options	#
Yes	21
Rather yes	39
Rather no	76
No	72
Total answers	**208**



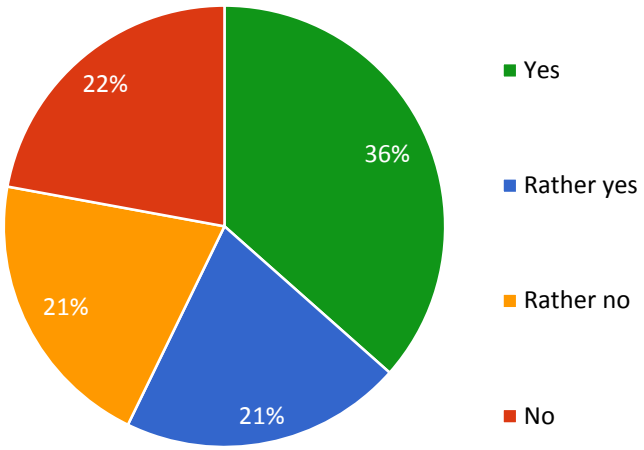
71% of the students were not distracted by using their devices during the lecture. Therefore more than two third of the students state that the use of their digital device had no negative effect on their ability to follow the lecture.

29% of the students say that they were distracted or slightly distracted from the lecture by the use of their devices. 1 out of 10 students state that they definitely were distracted from the lecture by using their digital devices.

[7] Would you have used your device during the lecture, if Presentr would not have been deployed today?

Single-Choice Question

Answer options	#
Yes	76
Rather yes	43
Rather no	43
No	46
Total answers	**208**



57% of the students would have used or rather used their digital devices, regardless of the deployment of Presentr during the lecture. 47% stated that they would not have used their devices if Presentr was not deployed in the respective lecture.

Distraction Potential

To measure the distraction potential of Presentr during the lectures the answers from the students, which stated that they were distracted or rather distracted by using their devices during the lecture, were further evaluated. Out of the 60 students that answered the question for distraction with yes or rather yes, 36 students would have used or rather used their device during the lecture even when Presentr had been not deployed. 24 out of the 60 students stated that they would have not used or rather used their device during the lecture.

Transferred to the whole survey population the following results emerge. Only 12% out of the 208 surveyed students were distracted or rather distracted by the use of their devices during the lecture and would not have been distracted from the lecture if Presentr would not have been deployed. Therefore it can be stated that the iARS tool Presentr issues a rather low distraction potential.

7. Lecturers Survey

To evaluate the demand of and experiences with integrated Audience Response Systems of the lecturers in university education, a survey for the lecturers at the Vienna University of Technology was conducted. The survey was designed after consulting the following literature "Survey research methods" [Fowler Jr, 2013], "Principles of Survey Research Part 2: Designing a Survey" [Kitchenham, 2002] and "Principles of Survey Research Part 3: Constructing a Survey Instrument" [Kitchenham & Pfleeger, 2002].

For the aim of the survey the following objectives were defined:

- **Experience with ARS.** What are the past experiences of the lecturers with Audience Response Systems?
- **Insight into current lecture preparation process.** Which steps are undertaken to prepare a lecture.
- **Insight into current lecture presentation process.** How do the lecturers hold their presentations?
- **Preference for interactive task types.** Which interactive task types of an ARS would the lecturers use?
- **Requirements for an iARS.** What requirements an iARS has to fulfil to be used by the lecturers?
- **Willingness to use an iARS.** How much lecturers would consider using an iARS in their future lectures?

7.1. Survey setting

Analysis Unit	University lectures
Geographical scope	Vienna University of Technology
Type of Sampling	Self-selection sampling
Instrument	Online questionnaire
Collection date	03.02.2016-19.02.2016
Number of sections	8
Number of questions	57
Estimated time for completion	15 minutes

The survey was designed and conducted with the web-based application Google Forms[31]. The invitation to participate in the survey was distributed, with the help of the Teaching Support Center[32], to all lecturers at the Vienna University of Technology, including external lecturers. The survey was structured into sections, each representing a page of the survey. For an example of the visual representation of the survey see appendix A1. All questions and answer options, inclusive additional question descriptions and ARS explanations, are listed in appendix A1.

[31] **Google Forms.** https://www.google.com/intl/en/forms/about
[32] **Teaching Support Center.** http://teachingsupport.tuwien.ac.at

Structure of the survey

Below each section of the questionnaire is described in detail, especially the goals of the respective section are outlined.

Section 0 – Introduction text

The introduction text mirrors the text of the e-mail with the request for participation. It explains the purpose of this survey and provides information about the author, supervisor and department. A short definition about ARS is given, including a small example of a response task, aiming for a better understanding what an ARS represents. The objects of the survey are explained shortly to provide an overview about the topics of the questionnaire. The anonymous participation and confidential handling of the generated data is stated, hoping that concerns about personal information protection are dispelled. The estimated time for completion and the due date are stated. An e-mail address is provided in case of any questions or request for more information about the survey. The full introduction text can be found in appendix A1.

Section 1 – Lecturer background

The background of the survey participant gets evaluated. Is he/she a lecturer, on a university, on which university? The field in which the participant gives lectures and how long he/she already holds lectures is questioned. The purpose is to evaluate if the participant of the survey is in the desired population group. Additionally it can be checked if the results differ significantly based on the field or the experience of the lecturers. Additionally information about the amount, type and size of the given lectures is requested.

Section 2 – Lecture preparation

The process of lecture preparation gets analyzed. Does the lecturer prepare any presentation slides and if yes, with which tools? Is it common to prepare additional notes and comments for individual slides? Do they export the presentation and provide it to their students before the lecture? The presentation slides update frequency and duration is questioned to give insight into how often and how much effort a lecturer is willing to commit for the improvement of his lecture material.

Section 3 – Presentation style

In this section the currently used presentation process gets illuminated. Which kind of equipment is used during the lecture? Which software tools are deployed during the lecture and how are they controlled? In preparation of a possible ARS deployment in the lecture, the lecturer is asked if he/she already uses interactive elements (e.g. small exercises, surveys or open questions with discussion). Additionally the time spending which such interactive tasks during the lectures is evaluated.

A sub paragraph requests information about what happens after the lecture presentation. Do the lecturers provide their presentation slides to their students, with or without their additional notes? If yes, is there a content difference between the presented and slides provided to the students?

Section 4 – Using an Audience Response System

The section starts with surveying the lecturers past experiences with ARS. Had they already used such a system? Which systems did they use and why did they choose that particular tool?

The second paragraph deals with the different interactive task types an ARS can provide. The lecturers are asked which of the tasks they would use in their lectures. Different types like survey, open question, scale, sort/rank, draw/sketch, quiz and heat map/region of interest are listed. After the type selection the lecturers are asked openly if they can imagine an alternative interactive task types suitable for their lectures. Additionally the attitude about presenting the results of the interactive tasks during the lecture gets requested.

The last paragraph collects information about the use of an integrated ARS. A short explanation about an iARS is provided, describing its main difference between traditional ARS. Then the participant is asked, if he/she would prefer using such a tool. Furthermore the lecturers get asked, if they would plan their interactive tasks at specific points in their presentation and if they would use a follow-me-mode where the students see and automatically follow the current slide of the speaker.

The section ends with asking the lecturers an open question about any additional features for an ARS or shortcomings of any used ARS.

Section 5 – Administration of an Audience Response System

In this section the functions and features regarding the management and administration of an ARS are evaluated. Would the lecturers export the interactive tasks results? If yes, to which application or format? Would they provide students access to the results of the interactive tasks after the lecture? Furthermore the lecturers are asked if they would use a function for a combined export of the presentation slides and interactive task results or a copy function for transferring interactive tasks from one lecture to another.

Another surveyed aspect is to inquire if the lecturers will use the ARS to check the attendance of the students in the lecture units. Then they were asked as additional question, if they will use the participation of a student in an interactive method as part of his/her grading.

The section ends with asking the lecturers an open question about any additional features for managing an ARS.

Section 6 – Introduce an Audience Response System

In this short section the willingness of using an ARS is requested. Beginning with the question how much effort a lecturer would invest to get trained with a new ARS. Following with how much effort they would invest in preparation to add interactive tasks to a single lecture. The section ends with the question, if they consider using an ARS in their future lectures. If the lecturers answer this question with no, an open question asking why is placed afterwards to collect the reasons of their decision or their concerns.

Section 7 – Only one click away

The last page should encourage the participates of the survey to leave their personal details there if they want to be informed about the results of the survey, would like to get more information about a web-based ARS currently developed or would like to test the currently developed ARS in one of their future lectures. An open final remarks input field at the end of the page leaves space for any additional thoughts about the survey, ARS or any other topic not addressed before.

7.2. Descriptive survey results

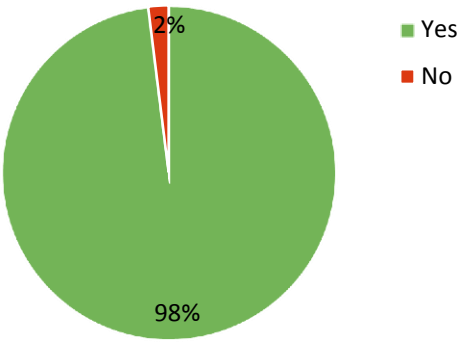
The descriptive results of the lecturers' survey are listed below.

7.2.1. Lecturer background

[1.1] Are you a lecturer?

Single-Choice Question

Answer options	#
Yes	100
No	2
Total answers	**102**

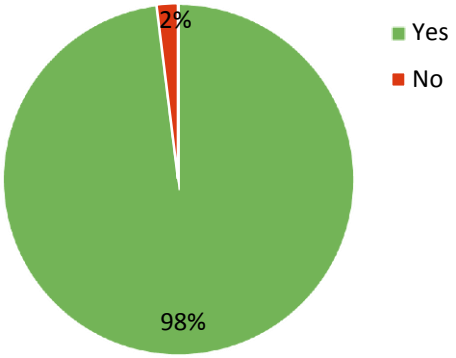


98% percent of the participants are lecturers and therefore in the expected population group.

[1.2] Are you a lecturer on a university?

Single-Choice

Answer options	#
Yes	100
No	2
Total answers	**102**



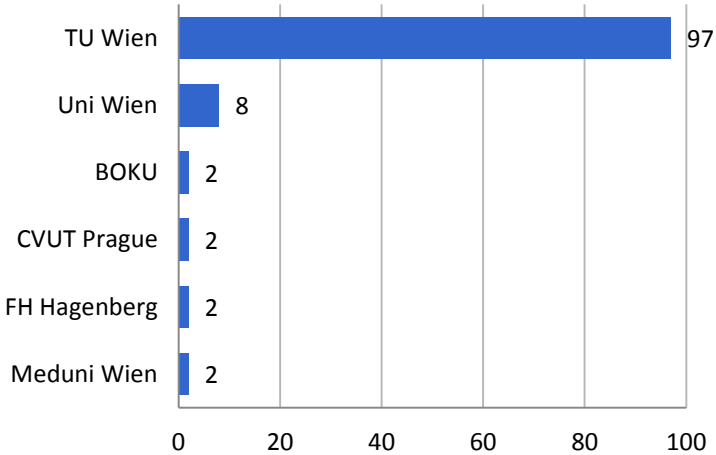
98% percent of the participants are university lecturers and therefore in the desired population group.

[1.3] If yes, on which university are you holding lectures?

Multiple-Choice with additional open input

Answer options	#	%
TU Wien	97	97%
Uni Wien	8	8%
BOKU	2	2%
CVUT Prague	2	2%
FH Hagenberg	2	2%
Meduni Wien	2	2%
Others	8	8%
Total answers	**121**	
Total participants	**n=100**	

One-time answers
FH Steyr, FH Technikum Wien, FH Wien, JKU Linz, KLPU Krems, SFU, TU Brno, WU Wien



Similar answers were united, like "Meduni Wien" and Medizinische Universität Wien".

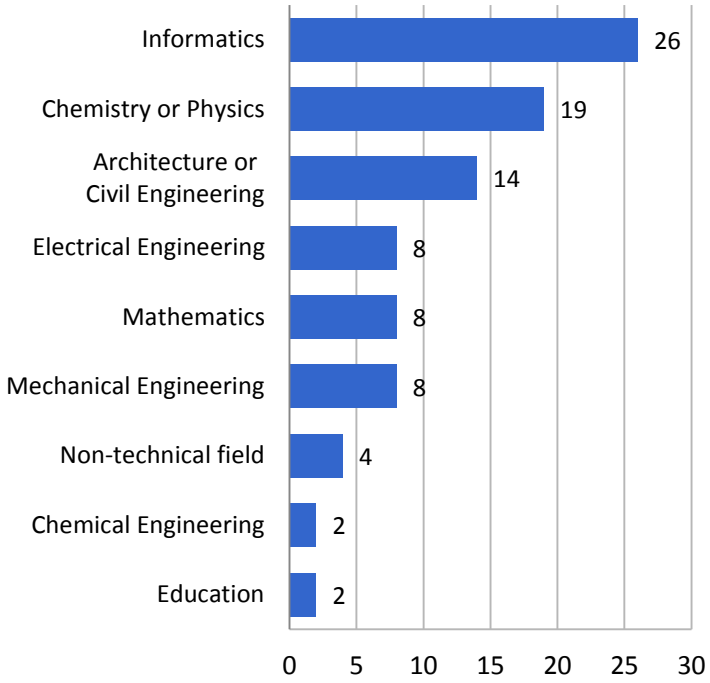
97% of the lecturers are lecturing at Vienna University of Technology, 8% are lecturing at University of Vienna.

[1.4] In which field are you giving lectures?

Multiple-Choice with additional open input

Answer options	#	%
Informatics	26	26%
Chemistry or Physics	19	19%
Architecture or Civil Engineering	14	14%
Electrical Engineering	8	8%
Mathematics	8	8%
Mechanical Engineering	8	8%
Non-technical field	4	4%
Chemical Engineering	2	2%
Education	2	2%
Others	10	10%
Total answers	**101**	
Total participants	**n=99**	

One-time answers
Biophysics, Biotechnology, Environmental Engineering, Geoscience and Remote Sensing, Management, Marketing, Methodology of empirical research, Mobile Computing, Project management, Statistics

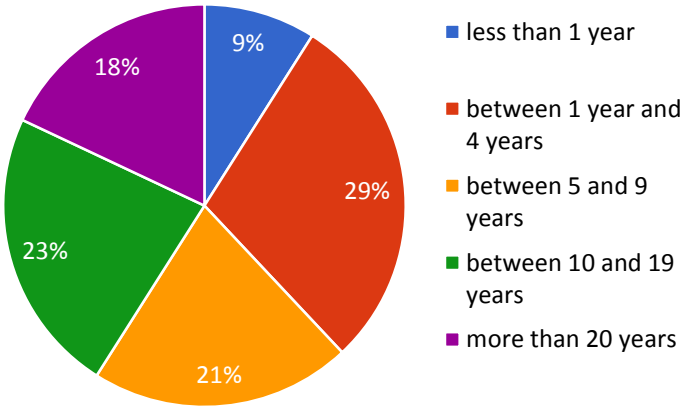


The lecturing fields of the participants are 94% technical and 8% non-technical. In the technical fields, informatics with 26%, Chemistry or Physics with 19% and Architecture or Civil Engineering with 14%, have the highest ratio.

[1.5] How long are you holding lectures on universities?

Single-Choice

Answer options	#
less than 1 year	9
between 1 year and 4 years	29
between 5 and 9 years	21
between 10 and 19 years	23
more than 20 years	18
Total answers	**100**

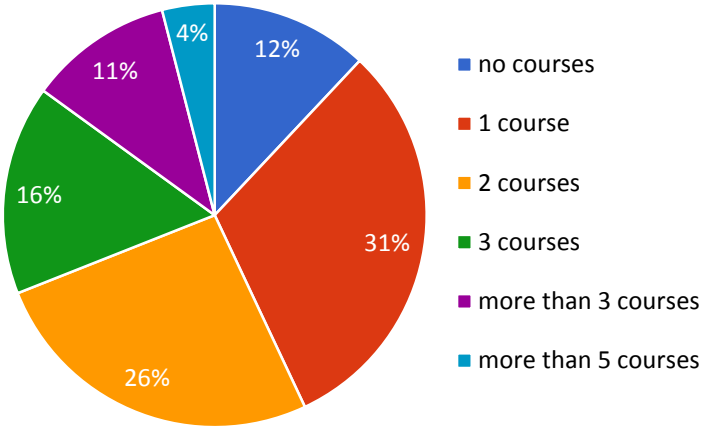


91% of the lecturers are holding their courses for more than one year. 62% of the participants are senior lecturers and are teaching for more than 5 years.

[1.6] How many courses are you holding next semester (summer term 2016)?

Single-Choice

Answer options	#
no courses	12
1 course	31
2 courses	26
3 courses	16
more than 3 courses	11
more than 5 courses	4
Total answers	**100**



88% of the lecturers are holding at least one course in summer term 2016. 57% of the lecturers are holding one or two courses in summer term 2016.

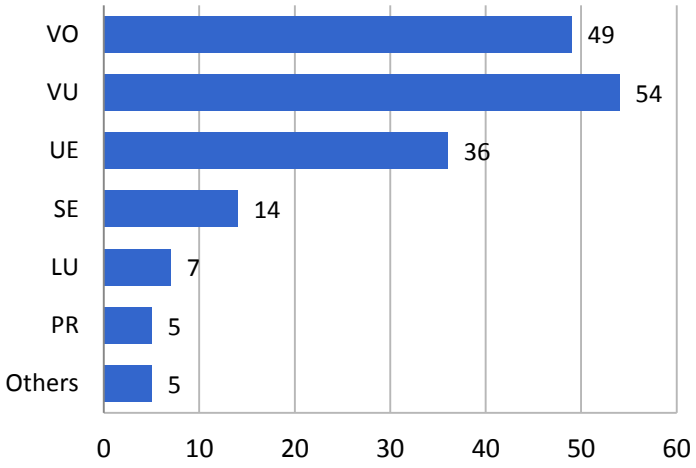
[1.7] What type of courses are you holding?

Multiple-Choice with additional open input

Answer options	#	%
VO (lecture)	49	50%
VU (lecture with integrated exercise)	54	55%
UE (exercise)	36	37%
SE (seminar)	14	14%
LU (laboratory exercise)	7	7%
PR (practical course)	5	5%
Others	5	5%
Total answers	**170**	
Total participants	**n=98**	

One-time answers

Field trip, Lecture + Excursion, PV, RU, VL

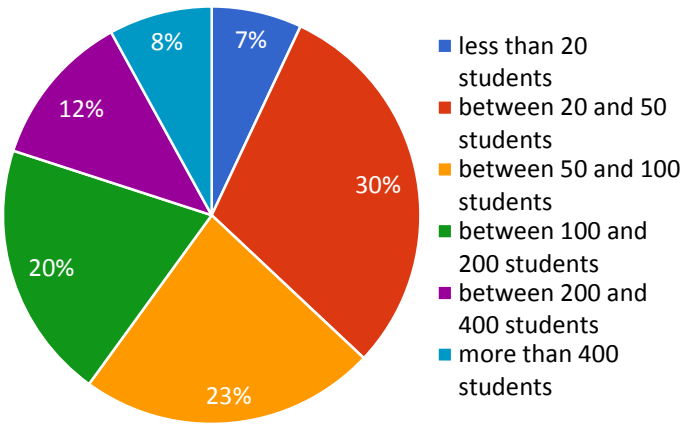


The lecturers, who participated in this survey, are mainly holding courses of the types, lecture, lecture with integrated exercise and exercise.

[1.8] What is the maximum number of students attending one of your courses?

Single-Choice

Answer options	#
less than 20 students	7
between 20 and 50 students	30
between 50 and 100 students	23
between 100 and 200 students	20
between 200 and 400 students	12
more than 400 students	8
Total answers	**100**



The maximum course sizes of the lecturers vary greatly, 37% have less than 50 students, 43% have between 50 and 200 students and 20% more than 200 students.

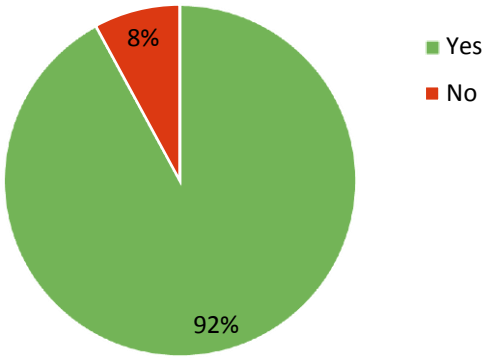
Summary of section 1

The evaluation of section 1 indicates a very good data quality. 98% of the participants were lecturers and therefore in the desired population group. Additionally, 97% the lecturers that participated in this survey are lecturing at the Vienna University of Technology. The lecturers are distributed over all study fields of the university with a small bias towards informatics, architecture or civil engineering and chemistry or physics. The experience of the lecturers is well distributed and range from junior to senior lecturers. The lecturers that participated in this survey have a great variety of lecture course sizes; it includes lecturers with less than 20 students in their courses and lecturers that hold large lectures with more than 400 students.

7.2.2. Lecture preparation

[2.1] Do you prepare digital presentation slides to support your lectures?
Single-Choice

Answer options	#
Yes	93
No	8
Total answers	**101**

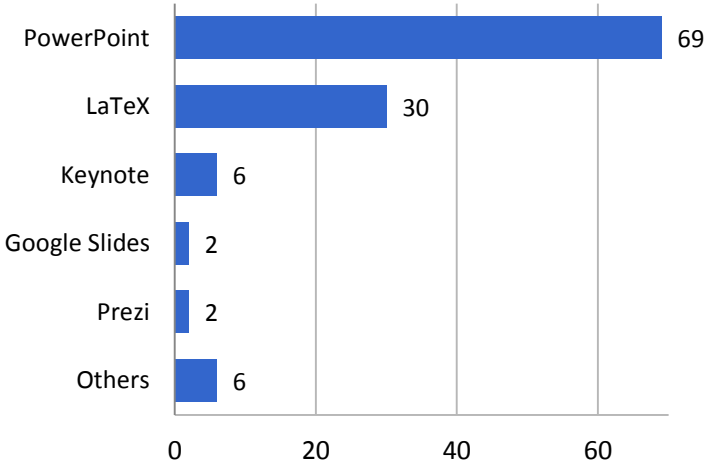


92% of the participants prepare digital presentation slides for their presentations.

[2.2] If yes, which tools are you use to prepare your slides?
Multiple-Choice with additional open input

Answer options	#	%
PowerPoint	69	73%
LaTeX	30	32%
Keynote	6	6%
Google Slides	2	2%
Prezi	2	2%
Others	6	6%
Total answers	**115**	
Total participants	**n=94**	

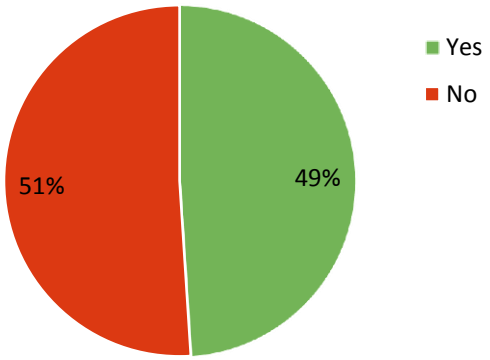
One-time answers
Apple draw, Indesign, LibreOffice-Presenter, Maple, PDF, PDF from Word



For their digital slide preparation 73% of the lecturers use PowerPoint, nearly 32% prepare them with LaTeX.

[2.3] Do you prepare additional notes and comments for individual slides?
Single-Choice

Answer options	#
Yes	48
No	50
Total answers	**98**

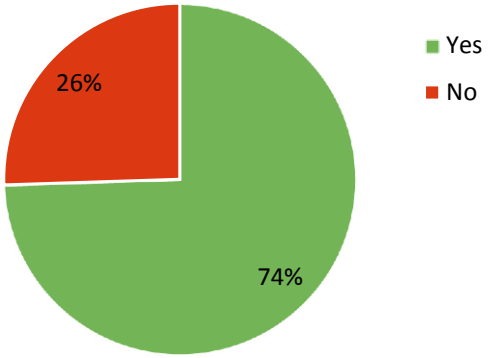


Approximately half of the lecturers prepare additional notes and comments on their presentation slides.

[2.4] Do you export your presentation slides as PDF for your presentation?

Single-Choice

Answer options	#
Yes	73
No	25
Total answers	**98**

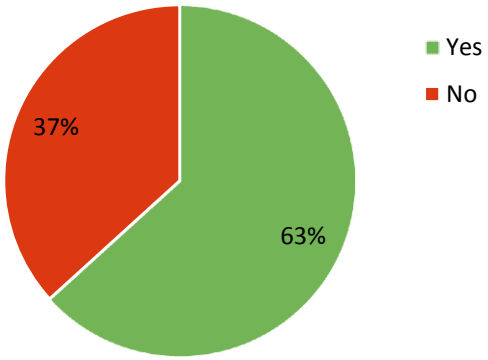


Approximately, three out of four lecturers, export their presentation slides as PDF for their presentation.

[2.5] Do you provide your presentation slides to your students before the lectures?

Single-Choice

Answer options	#
Yes	62
No	36
Total answers	**98**

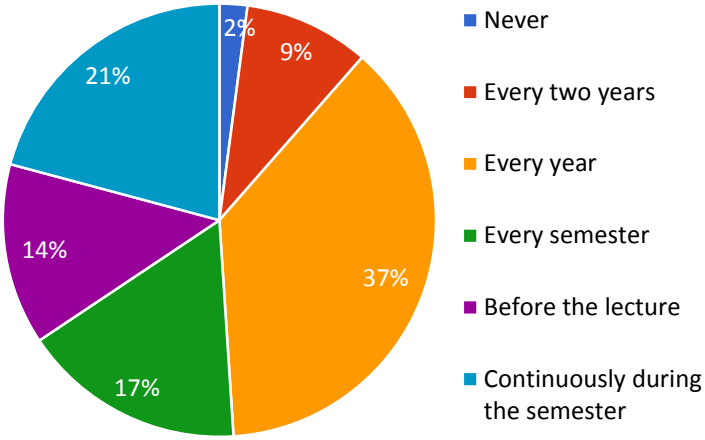


63% of the lecturers provide their presentation slides to the students before the lecture.

[2.6] How often do you update slides from previous courses?

Single-Choice

Answer options	#
Never	2
Every two years	9
Every year	36
Every semester	16
Before the lecture	13
Continuously during the semester	20
Total answers	**96**

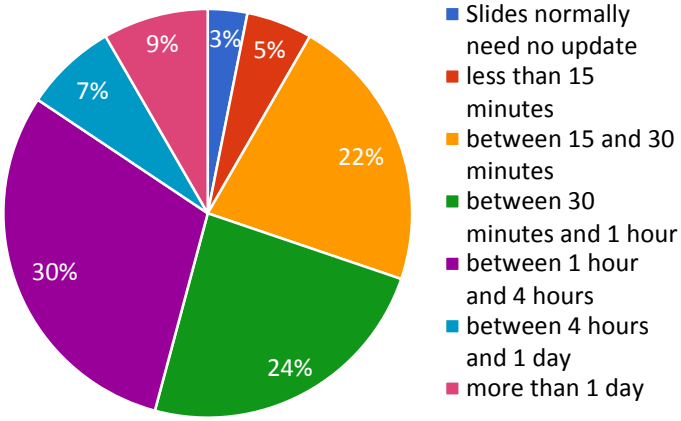


51% of the lecturers update their presentation slides at least once every semester. 37% update them every year.

[2.7] How much effort do you need on average to update these slides for a single lecture unit?

Single-Choice

Answer options	#
Slides normally need no update	3
less than 15 minutes	5
between 15 and 30 minutes	21
between 30 minutes and 1 hour	23
between 1 hour and 4 hours	29
between 4 hours and 1 day	7
more than 1 day	8
Total answers	**96**



46% of the lectures need between 15 minutes and 1 hour to update their presentation slides for a single lecture unit. 30% of the lectures invest between 1 and 4 hours for this task.

Summary of section 2

92% of the lecturers prepare digital presentation slides for their lecturers and are therefore in the potential target group for using an integrated Audience Response System. Every program that was mentioned for preparing presentation slides has the ability to export the slides to the PDF format. This relativizes the constraint of Presentr to only support PDF files as input format. 74% of the lecturers, who prepare presentation slides, already export their slides as PDF files. This subset of lecturers would have no cut-back if they use Presentr to present their presentation slides.

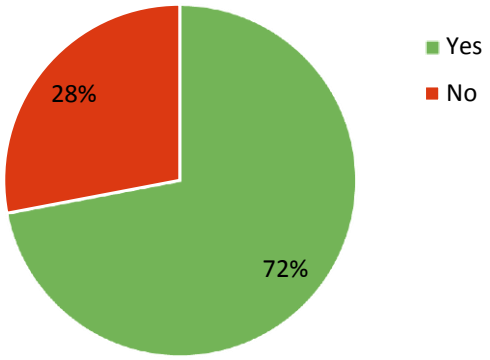
Analyzing the provided slide update frequencies the following interpretations arise. 52% of the lecturers can integrate the additional effort, needed for preparing interactive tasks within the ARS, into their slide preparation process because they are updating their slides at least once per semester. 37% of the lecturers update their slides once per year and therefore are either holding a course only once per year or are holding the course two semester long with the same presentation slides. 35% of the lecturers are updating their slides continuously during the semester or before the respective lecture unit. This group will need the re-upload function provided by Presentr to update their slides without losing prepared or finished interactive tasks.

7.2.3. Presentation style

[3.1] Do you use any supporting equipment during your lecture?

Single-Choice

Answer options	#
Yes	72
No	28
Total answers	**100**



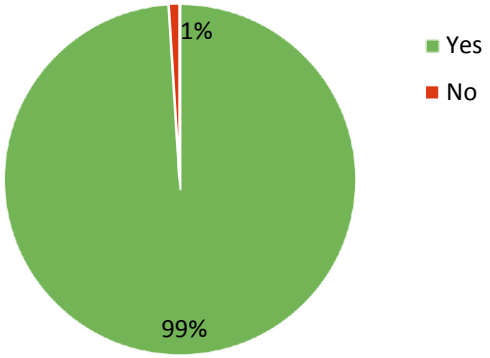
As consequence for an unclear question formulation, this question had often been misinterpreted. The original intention was to check if the lecturers use any analog or digital presentation support tools during their lectures. In question 3.1* the answers of the participants have been re-evaluated with the original intention.

[3.1*] Do you use any supporting equipment during your lecture?

Single-Choice

Answer options	#
Yes*	99
No	1
Total answers	**100**

*Participants that have indicated in subsequent questions, that they are using any analog or digital presentation support.



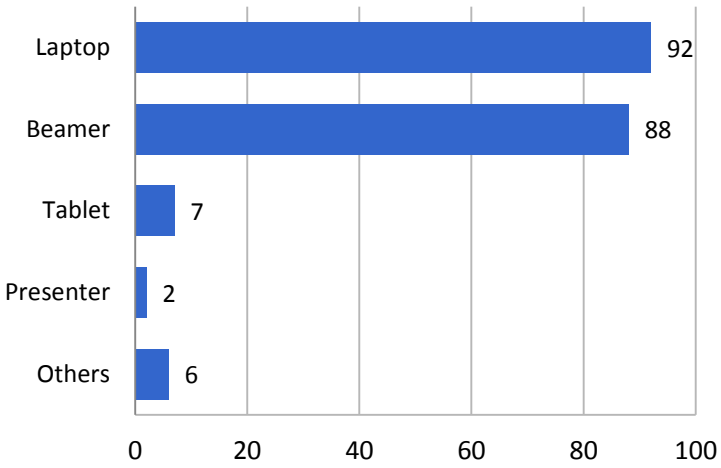
99% of the lecturers are using any kind of analog or digital supporting equipment during their lectures.

[3.2] Do you use digital presentation support during your lectures?

Multiple-Choice with additional open input

Answer options	#	%
Laptop	92	94%
Beamer	88	90%
Tablet	7	7%
Presenter	2	2%
Others	6	6%
Total answers	**195**	**100%**
Total participants	**n=98**	

One-time answers
Desktop, Digital Whiteboard, document camera + paper + pencil, Dokumentenkamera, Live Streaming, Micro



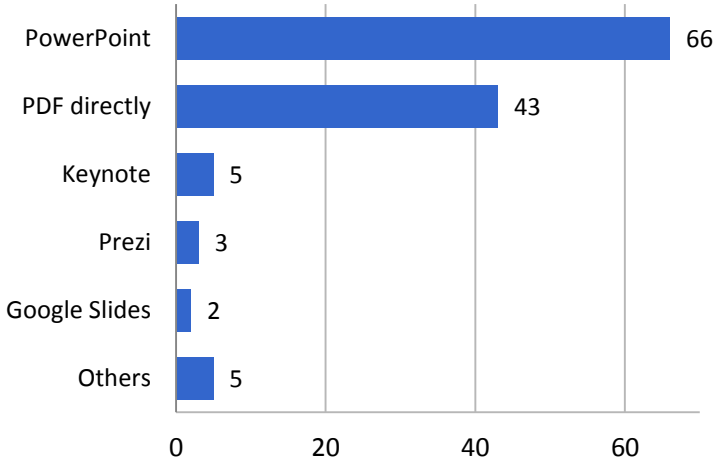
Nearly 94% of the lecturers are using a laptop, nearly 90% a beamer/projector during their lectures.

[3.3] Do you use presentation software during your lecture? (This question is not about how you generate your presentation slides)

Multiple-Choice with additional open input

Answer options	#	%
PowerPoint	66	68%
Presenting PDF directly	43	44%
Keynote	5	5%
Prezi	3	3%
Google Slides	2	2%
Others	5	5%
Total answers	**124**	
Total participants	**n=97**	

One-time answers
Excel, LibreOffice-Presenter, MODDE, Web Browser (Chrome), Slideshare

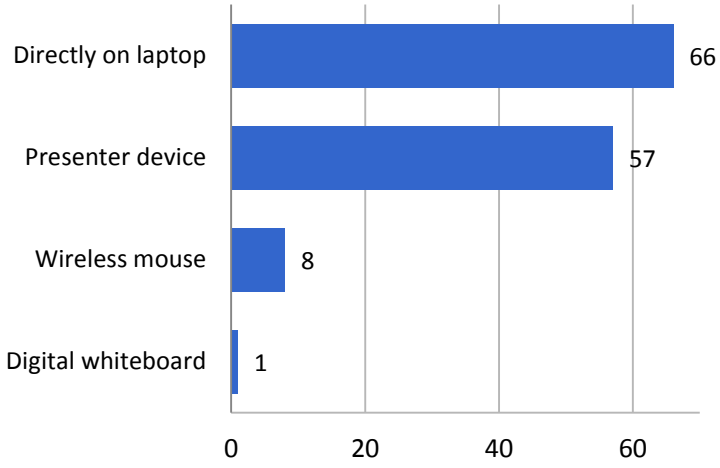


For presenting their presentation slides 68% of the lecturers are using PowerPoint during their lectures. 44% present their presentation slides directly out of a PDF file.

[3.4] How do you control your presentation during your lectures?

Multiple-Choice with additional open input

Answer options	#	%
Directly on laptop/tablet	66	68%
Wireless pointer/ Presenter device	57	59%
Wireless mouse	8	8%
Digital whiteboard	1	1%
Total answers	**132**	
Total participants	**n=97**	



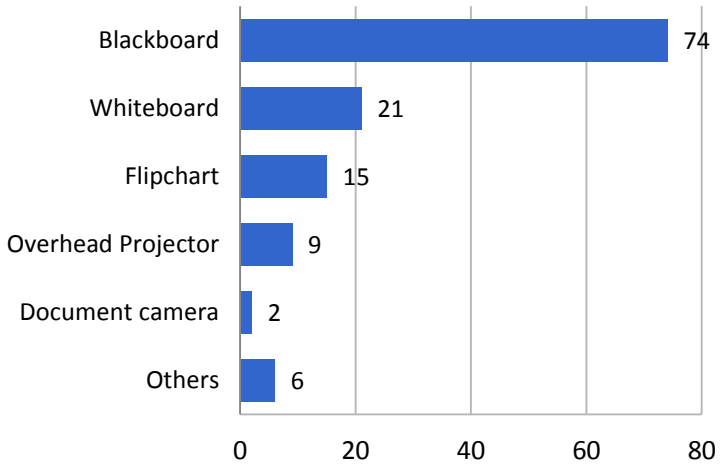
For controlling their presentation, 68% of the lecturers are using their laptop/tablet directly; nearly 59% are using a wireless pointer/presenter device for this task.

[3.5] Do you use any (additional) analog tools during your lectures?

Multiple-Choice with additional open input

Answer options	#	%
Blackboard	74	88%
Whiteboard	21	25%
Flipchart	15	18%
Overhead Projector	9	11%
Document camera	2	2%
Others	6	7%
Total answers	**127**	
Total participants	**n=84**	

One-time answers
Demonstrations, digital whiteboard, excursion, exp. hydr. models, experiments, printed handouts and worksheets



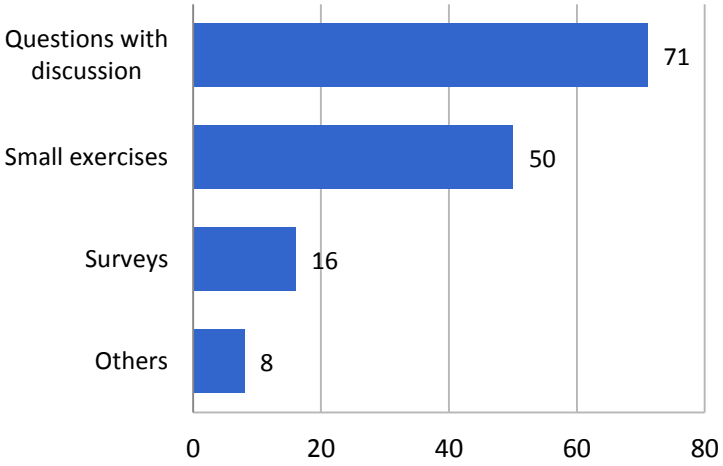
The traditional blackboard is still widely in use; 88% of the lecturer are using a blackboard, 25% a whiteboard, nearly 18% a flipchart and nearly 11% an overhead projector during their lecturers.

[3.6] Do your lectures have interactive elements?

Multiple-Choice with additional open input

Answer options	#	%
Questions with discussion	71	81%
Small exercises	50	57%
Surveys	16	18%
Others	8	9%
Total answers	**145**	
Total participants	**n=88**	

One-time answers
Active pursuit of conclusions, demo material with discussion, expert interviews, group discussions, pair/group activities, presentations by students, short questions, small presentations

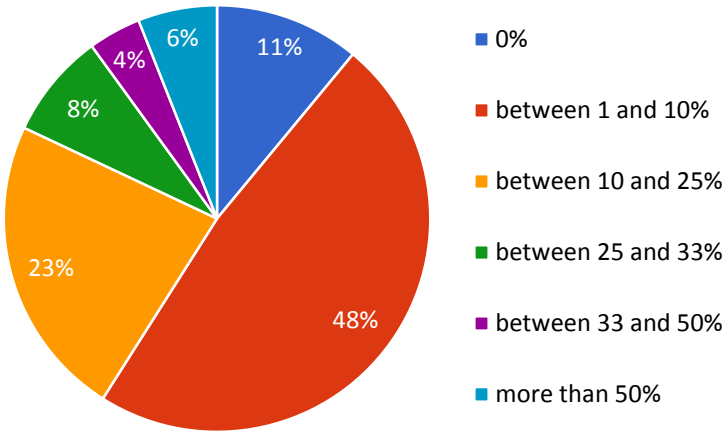


A high ratio of lecturers enriches their courses with interactive tasks. Nearly 81% are asking their students an open question and discuss the answers; nearly 57% enroll small exercises and 18% conduct surveys during their lecture.

[3.7] How much time do you spend with interactive elements during your lectures in percent?

Single-Choice

Answer options	#
0%	11
between 1 and 10%	48
between 10 and 25%	23
between 25 and 33%	8
between 33 and 50%	4
more than 50%	6
Total answers	**100**

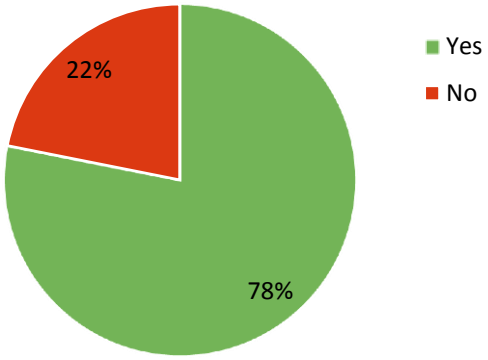


48% of the lecturers invest 1 to 10 percent of their lecturing time in conducting interactive activities. 23% spend 10 to 25 percent and 18% of the lecturers reserve more than 25 percent of their lecturing time for interactive tasks.

[3.8] Do you provide your presentation slides to your students after the lectures?

Single-Choice

Answer options	#
Yes	75
No	21
Total answers	**96**

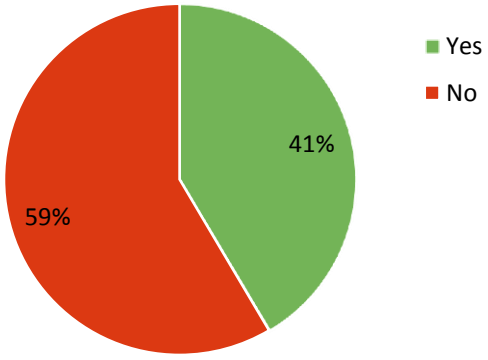


78% of the lecturers provide their presentation slides to their students after their lectures.

[3.9] Do you provide the additional notes and comments (if any) to your students?

Single-Choice

Answer options	#
Yes	39
No	55
Total answers	**94**

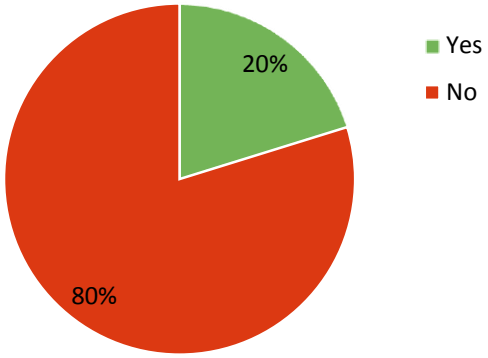


Only 41% of the lecturers provide their additional notes and comments for individual presentation slides to their students after the lecture.

[3.10] Is there any difference between presented and provided slides?

Single-Choice

Answer options	#
Yes	19
No	75
Total answers	**94**



Four out of five lecturers, provide the presented set of presentation slides to their students.

Summary of section 3

First the different presentation styles of the lecturers get evaluated. In total 100 lecturers participated in this section of the survey.

No analog or digital tool support. Only one participant of the survey stated that he/she uses no tool support during their course. The participant has indicated that he/she only holds laboratory exercises where students work on their experiments.

Only analog tool support, e.g. blackboard, whiteboard, overhead projector. Only two out of the 99 lecturers, who use tool support, have declared that they enrich their lectures only with analog tools.

Simple digital tool support, e.g. laptop, beamer. Out of 97 lecturers, who use digital tool support, 26 indicate that they use only simple digital tools to support their lectures. These lecturers are an ideal target group for deploying an integrated Audience Response System in their lectures, because it would require only minimal changes in their presentation process.

Support through presentation software. 62 out of the 97 lecturers are using presentation software during their lectures. Out of the 62 lecturers 20 have stated that they also present their presentation slides directly from a PDF file. For the 42 lecturers, which solely present their slides with presentation software, a transition process, depending on the used presentation software functionalities, would be required to convert their lectures into lectures supported by Presentr.

Enriched with Audience Response Systems. Out of the 97 lecturers, who use digital tool support, 9 have already used an ARS tool. 5 of them have used Presentr during the pilot test or case study. Other Audience Response Systems that were stated include invote.de[33], i>clicker[34], Pingo[35] and Kahoot![36].

[33] **invote.de.** http://invote.de
[34] **i>clicker.** https://www1.iclicker.com
[35] **Pingo.** https://pingo.upb.de
[36] **Kahoot!.** https://getkahoot.com

Second the additionally equipment used during the lectures is evaluated.

Nearly 90% of the lecturers are using a projector device (i.e. beamer) during their lectures. Nearly 59% of the lecturers are using a presenter device for controlling their presentation slides and mark important areas of their slides.

Out of the 97 lecturers, who use digital tools support, 79 i.e. 81% are using additional analog tools during their lecture. The most common used additional analog tool is the blackboard which nearly 90% of the 79 lecturers are using.

Thirdly already used interactive elements during the lectures and the provision of the presentation slides are evaluated.

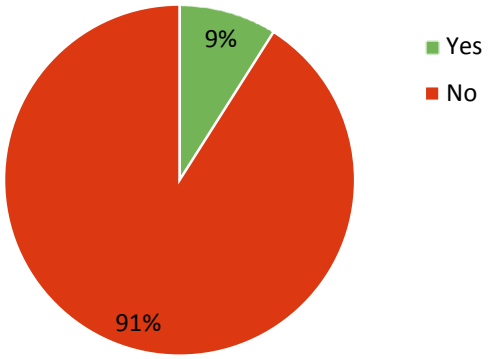
88 out of 100 lecturers already enrich their lecture presentations with interactive elements. Out of the 88 lecturers, nearly 81% are asking their students open questions and discuss the answers with them; nearly 57% are conducting small exercises and 18% of the lecturers are surveying their students during their lectures.

Currently Presentr could support 74 of the 88 lecturers, i.e. 84%, that already conduct interactive elements during their lectures, with its implemented interactive task type's open question, survey and quiz.

7.2.4. Using an Audience Response System

[4.1] Did you use a Classroom or Audience Response System (ARS) in your past lectures?
Single-Choice

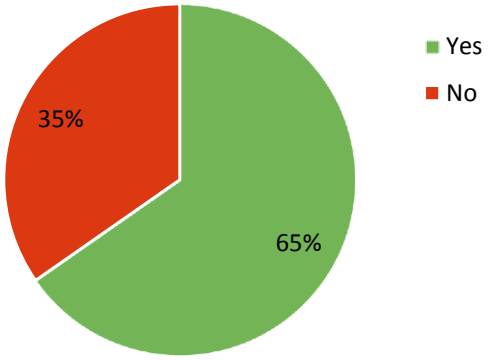
Answer options	#
Yes	9
No	91
Total answers	**100**



Only 9% of the lecturers have used an Audience Response System in one of their past lectures

[4.2] Would you use the ARS for single choice surveys?
Single-Choice

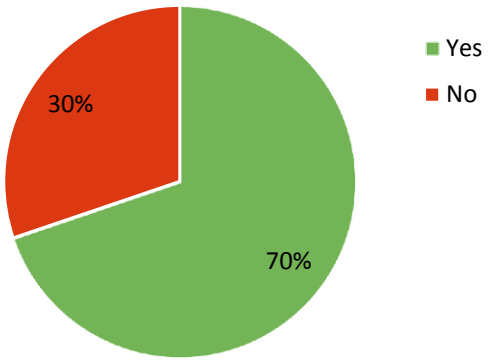
Answer options	#
Yes	64
No	34
Total answers	**98**



65% of the lectures would use the ARS with the interactive task type single choice surveys.

[4.3] Would you use the ARS for multiple choice surveys?
Single-Choice

Answer options	#
Yes	67
No	29
Total answers	**96**

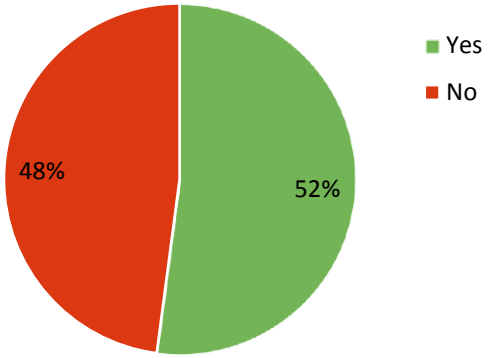


70% of the lectures would use the ARS with the interactive task type multiple choice surveys.

[4.4] Would you use the ARS to ask open questions?

Single-Choice

Answer options	#
Yes	50
No	46
Total answers	**96**



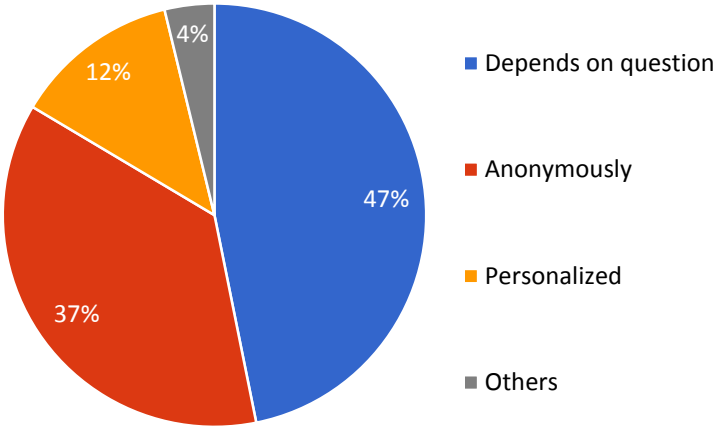
52% of the lectures would use the ARS with the interactive task type open answer.

[4.5] How should students answer open questions via the ARS?

Single-Choice

Answer options	#
Depends on question	37
Anonymously	29
Personalized	10
Others	3
Total answers	**79**

One-time answers
Depends on students, use social media / SMS / Twitter, would not use it for open questions

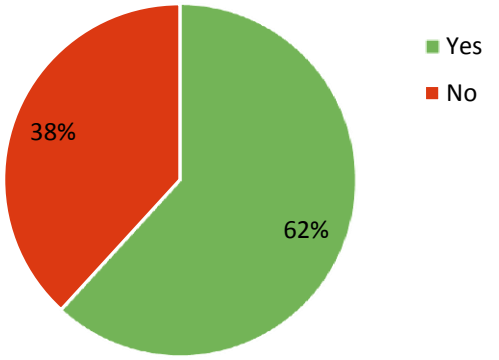


While 37% would ask open questions only anonymously and 12% only personalized, the majority of the lecturers would set the mode of anonymity depending on the question they ask.

[4.6] If the students can rate the answers of each other, would you allow it?

Single-Choice

Answer options	#
Yes	55
No	34
Total answers	**89**

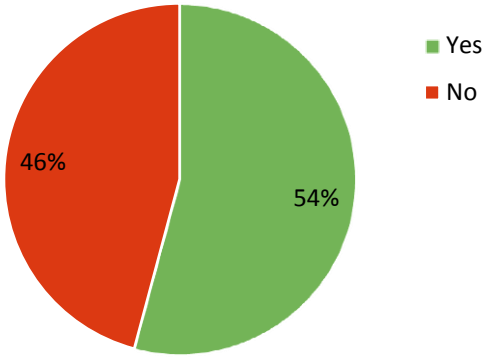


62% of the lectures would allow the students to rate the answers of the others.

[4.7] Would you use the Scale interactive task?

Single-Choice

Answer options	#
Yes	52
No	44
Total answers	**96**

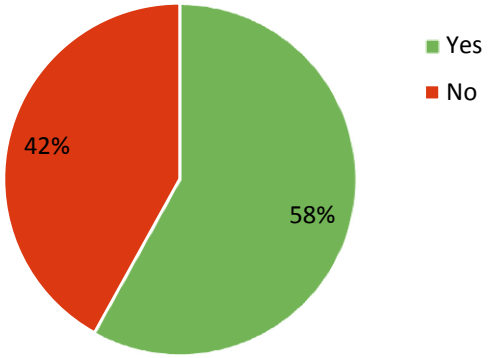


54% of the lectures would use the ARS with the interactive task type scale, where students can choose a number in a predefined scale (e.g. 1 to 10).

[4.8] Would you use the Sort/Rank interactive task?

Single-Choice

Answer options	#
Yes	54
No	39
Total answers	**93**

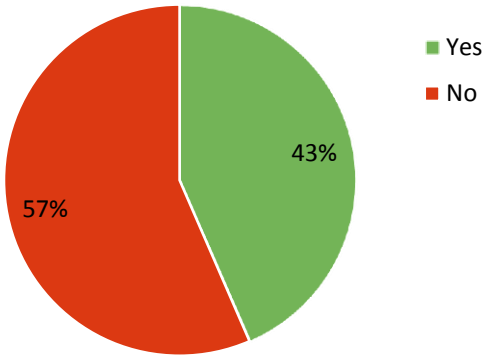


58% of the lectures would use the ARS with the interactive task type sort/rank, where students can rank predefined items in their own order.

[4.9] Would you use the Draw/Sketch interactive task?

Single-Choice

Answer options	#
Yes	40
No	52
Total answers	**92**

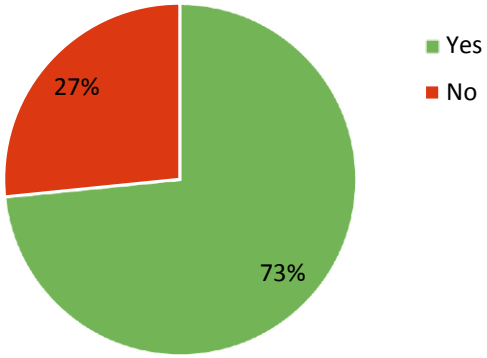


43% of the lectures would use the ARS with the interactive task type draw/sketch, where students can respond to a question with a drawing.

[4.10] Would you use the Quiz interactive task?

Single-Choice

Answer options	#
Yes	69
No	25
Total answers	**94**

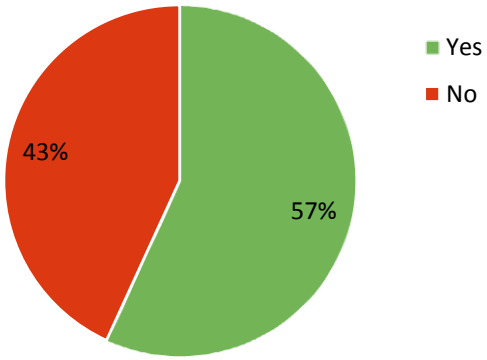


73% of the lectures would use the ARS with the interactive task type quiz survey.

[4.11] Would you use the Heatmap interactive task?

Single-Choice

Answer options	#
Yes	54
No	41
Total answers	**95**

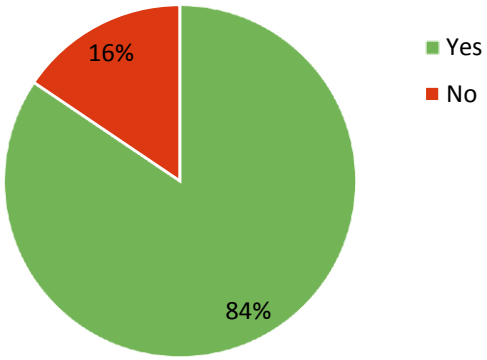


57% of the lectures would use the ARS with the interactive task type heat map / region of interest, where students can click on a position within a presentation slide.

[4.12] Would you present the results of the interactive tasks during your lectures (fast feedback)?

Single-Choice

Answer options	#
Yes	76
No	14
Total answers	**90**

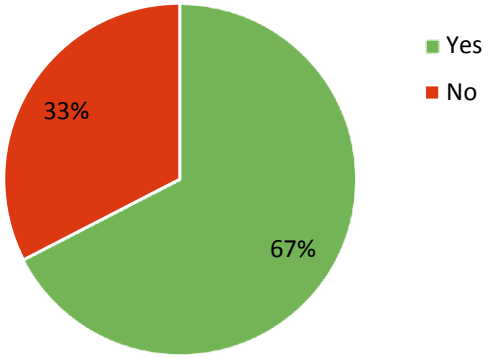


84% of the lecturer would present and discuss the results of the interactive tasks during their lectures.

[4.13] Would you present good answers from the last semesters during the lecture?

Single-Choice

Answer options	#
Yes	60
No	29
Total answers	**89**

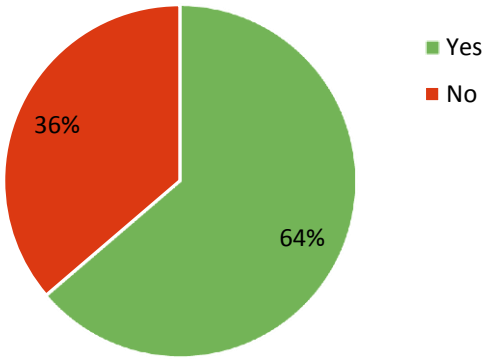


67% of the lecturers would present valuable answers from the last semesters during their lecturers.

[4.14] Would you prefer controlling your presentation slides and interactive tasks with one tool?

Single-Choice

Answer options	#
Yes	58
No	33
Total answers	**91**

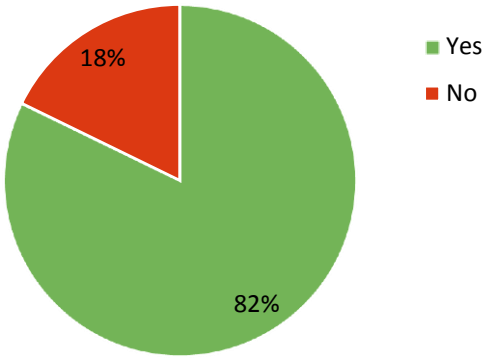


64% of the lecturers would prefer one tool for controlling their presentation slides and the interactive tasks.

[4.15] Would you plan response methods at specific points in your presentation, e.g. at slide x?

Single-Choice

Answer options	#
Yes	74
No	16
Total answers	**90**

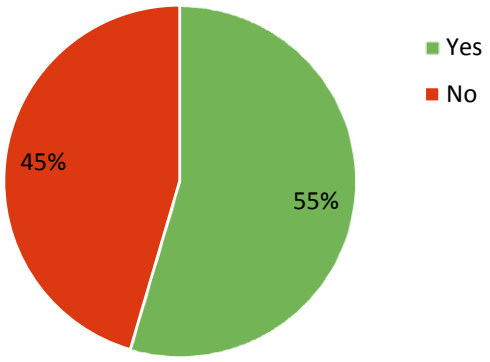


Interactive Tasks are mostly planned at specific points in a presentation, 82% of the lecturers can specify the exact slide where interactivity should be conducted.

[4.16] Would you use a feature, where students can see the presentation slides on their devices and automatically follow the current slide of the speaker (follow-me mode)?

Single-Choice

Answer options	#
Yes	48
No	40
Total answers	**88**



Just over half (55%) of the lecturers would use the follow-me-mode, where students can follow the current presentation slide of the lecturer on their devices.

Summary of section 4

In this section required functions and features that an Audience Response System should support have been asked. To summarize the results of the different interactive task types, table 21 lists each interactive task type ranked by its popularity. Interactive task types that are currently supported by Presentr are marked with a *.

Interactive task type	Relative popularity
Quiz*	73%
Multiple-Choice Survey*	70%
Single-Choice Survey*	65%
Sort / Rank	58%
Region of Interest / Heat Map	57%
Scale / Numeric	54%
Open Question*	52%
Draw / Sketch	43%

Table 21: Results of interactive task types in the lecturers survey

Other requirements of an iARS, besides the interactive task types, get evaluated and summarized in table 22. The table lists the requirements and their popularities by the participants of the survey.

Requirements	Relative popularity
In the interactive task open question the students can rate the answers of each other.	62%
The results of the interactive tasks can be displayed on the projector device during the lecture.	84%
Answers from past lectures, held in last semesters, can be presented during the lecture.	67%
The system hints the lecturer or auto starts an interactive task at a specific slide.	82%
The students can see and follow the presentation slides of the lecturer on their devices.	55%

Table 22: Results of interactive task requirements in the lecturers survey

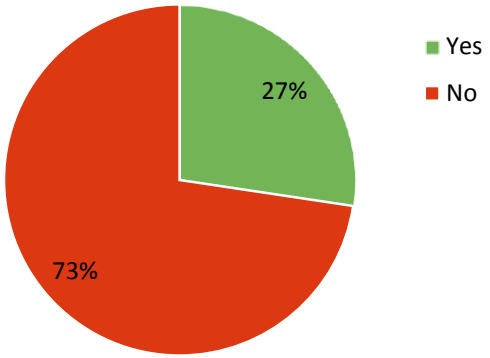
Additionally 64% of the lecturers would prefer controlling their presentation slides and interactive tasks with one tool, which is one of the main benefits an iARS can deliver.

7.2.5. Administration of an Audience Response System

[5.1] If the system can identify each student with his/her student account, would you use the ARS to check the attendance of the students?

Single-Choice

Answer options	#
Yes	26
No	69
Total answers	**95**

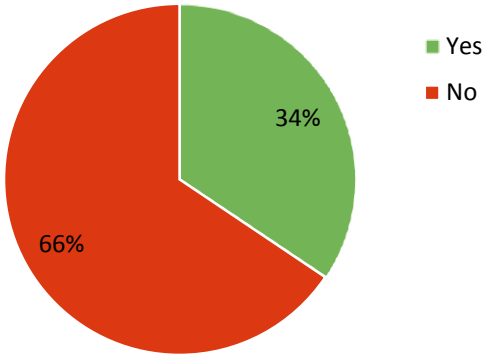


Only 27% of the lecturers would use an Audience Response System to check the attendance of the students.

[5.2] Would you use the active participation of a student in an interactive task as part of his/her grading?

Single-Choice

Answer options	#
Yes	32
No	61
Total answers	**93**

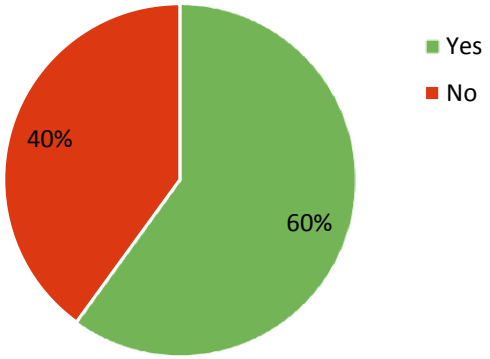


Only 34% of the lecturers would use the active participation of the students in an interactive task as part of their grading.

[5.3] Would you export the results of the interactive tasks for further processing?

Single-Choice

Answer options	#
Yes	57
No	38
Total answers	**95**

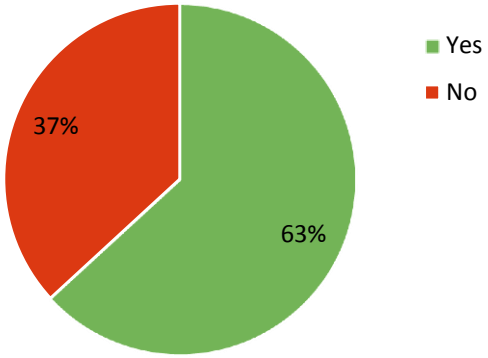


Some participants have answered this question with no, but answered the subsequent question positive. In question 5.3* the answers of the participants have been re-evaluated.

[5.3*] Would you export the results of the interactive tasks for further processing?

Single-Choice

Answer options	#
Yes	60
No	35
Total answers	**95**

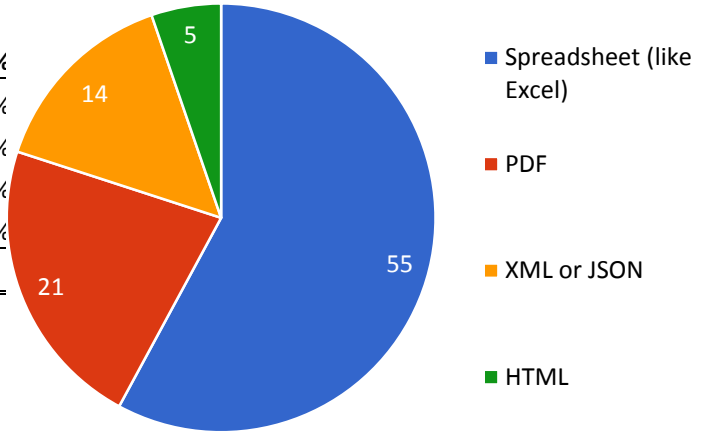


63% of the lecturers would export the results of the interactive tasks for further evaluation.

[5.4] If, yes to which application/format would you export the data?

Multiple-Choice with additional open input

Answer options	#	%
Spreadsheet (like Excel)	55	92%
PDF	21	35%
XML or JSON	14	23%
HTML	5	8%
Total answers	**95**	
Total participants	**n=60**	

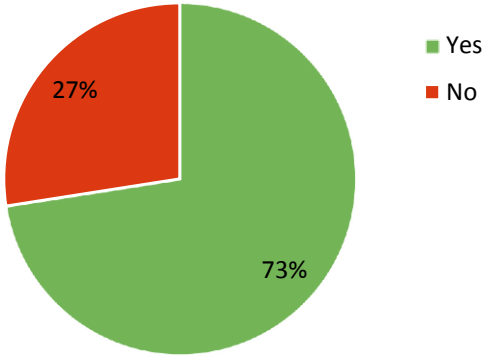


Nearly 92% of the lecturers would export the interactive tasks results data, to a spreadsheet-program readable format. Additionally 35% would export the data to PDF and 23% to a format that can be used for further automatic processing, like XML or JSON.

[5.5] Would you provide students access to the results of the interactive tasks after the lecture?

Single-Choice

Answer options	#
Yes	66
No	25
Total answers	**91**

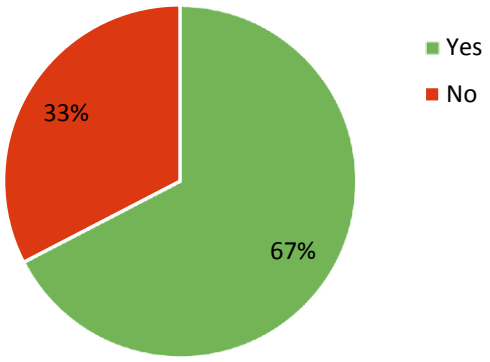


73% of the lecturers would provide the results of the interactive tasks to their students after their lectures.

[5.6] Would you use a function, where your presentation slides and the results of the interactive tasks get bundled and exported into one PDF?

Single-Choice

Answer options	#
Yes	62
No	30
Total answers	**92**

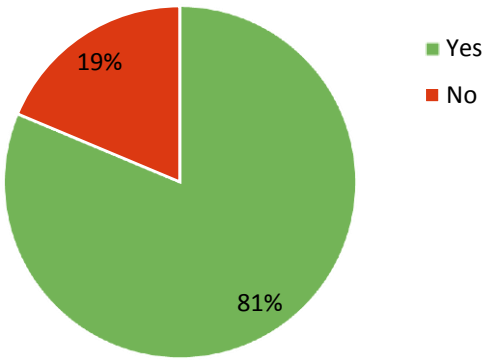


More than two out of three (67%) lecturers would use a combined export function, which allows an integrated export of the interactive tasks results and the presentation slides within one PDF file.

[5.7] Would you use a function to copy your interactive tasks (questions for the students) from a lecture last semester to a lecture this semester?

Single-Choice

Answer options	#
Yes	74
No	14
Total answers	**91**



81% of the lecturers would use a copy function for their interactive tasks.

Summary of section 5

In this section the possible usage of an ARS to check attendance or grade the active participation is evaluated. Additionally functions and features that are related to the administration of an Audience Response System are evaluated.

27% of the lecturers would use the ARS for checking attendance of the students in their lecture units. This could be an improvement and acceleration of the traditional analog attendance list process. 73% of the lecturers would not use the ARS for this task and therefore check the attendance of the students traditionally or have no need for checking student attendance in their lectures.

34% of the lecturers would you use the interactive tasks of the ARS as summative assessments and therefore as part of students grading. This demand could be explained because active participation is an integral part of the lecturing type VU (lecture with integrated exercise), which 55% of the lecturers are holding. This could be a change to digitalize the active participation part of the student's grade, however further research is needed to explore this possibility. 66% of the lecturers would use the interactive tasks of the ARS only for formative assessments.

To summarize the evaluation of the requirements referencing to the administration of an iARS, table 23 lists the respective requirements and their popularities by the participants of the survey.

Requirements	Relative popularity
The results of the interactive tasks can be exported for further processing.	63%
The results of the interactive tasks can be exported to a file format readable by spreadsheet programs.	92%
The students can access the results of the interactive tasks after the lecture.	73%
The system supports a combined export, where presentation slides and the results of the interactive tasks are bundled into one PDF file.	67%
The interactive tasks can be copied from a lecture last semester to a lecture this semester.	81%

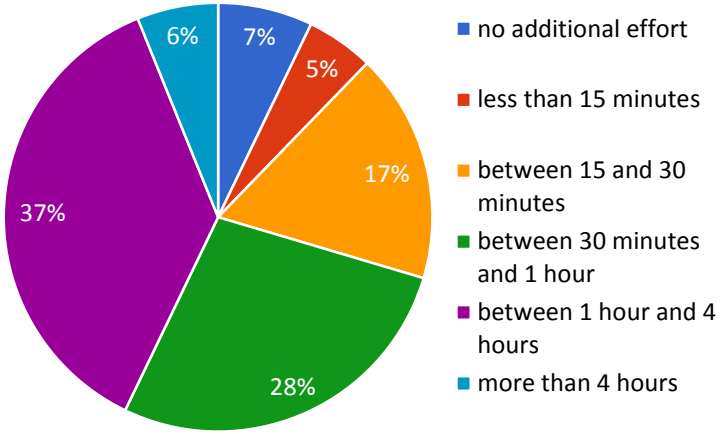
Table 23: Results of administrative requirements in the lecturers survey

7.2.6. Introduce an Audience Response System

[6.1] How much effort would you invest to get trained / train yourself with a new Audience Response System?

Single-Choice

Answer options	#
no additional effort	7
less than 15 minutes	5
between 15 and 30 minutes	17
between 30 minutes and 1 hour	27
between 1 hour and 4 hours	36
more than 4 hours	6
Total answers	**98**

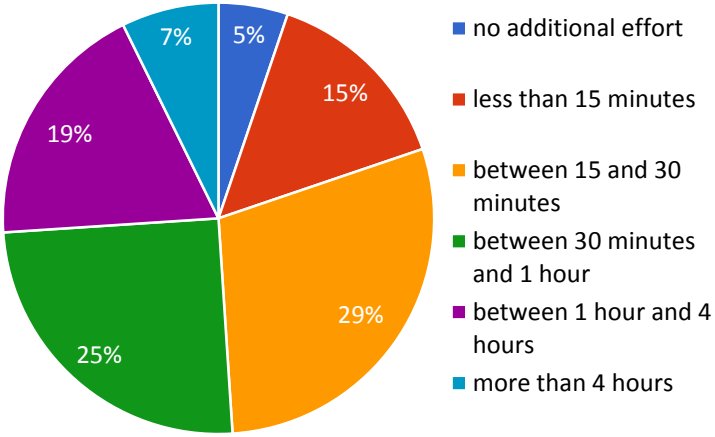


Nearly 45% of the lectures would invest between 15 minutes and 1 hour for learning a new Audience Response System. 37% of the lectures would invest between 1 and 4 hours for this task.

[6.2] How much effort would you invest in preparation to add interactive elements, within an ARS, to a single lecture?

Single-Choice

Answer options	#
no additional effort	5
less than 15 minutes	14
between 15 and 30 minutes	28
between 30 minutes and 1 hour	24
between 1 hour and 4 hours	18
more than 4 hours	7
Total answers	**96**

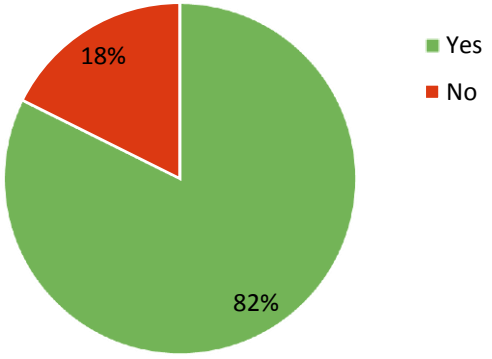


54% of the lectures would invest between 15 minutes and 1 hour for adding interactive tasks to a single lecture. 15% would invest less than 15 minutes and 26% more than an hour for this task.

[6.3] Can you consider using an ARS including the described features in your future lectures?

Single-Choice

Answer options	#
Yes	84
No	18
Total answers	**102**



82% of the lecturers would consider using an Audience Response System in their future lectures.

Summary of section 6

12% of the lecturers would invest less than 15 minutes to get trained/ train themselves with a new Audience Response System. 88% would invest at least 30 minutes into this task. This means that an overview over the base functionalities of the ARS tool should be explain- and understandable within 30 minutes to reach 88% of the lecturers. 43% would invest more than one hour to dig deeper into the system, they need detailed tutorials and demonstration functions for learning the system precisely.

15% of the lecturer would invest less than 15 minutes to add interactivity within an ARS to one of their lectures, therefore only small questions or exercises would be suitable. 80% of the lecturer would invest at least 30 minutes to add interactive tasks to a single lecture. This means that the Audience Response System should support adding, checking and testing interactive tasks within 30 minutes.

In the end of the survey the willingness to use an integrated Audience Response System is evaluated. The result is highly positive with 82% of the lecturers or more than 4 out of 5 lecturers would consider using an iARS in their future lectures. Additionally the subsequent open question why they cannot consider using an iARS has been evaluated. 4 lecturers stated that an iARS would not be useful for their type of lectures. Two lecturers responded that they do not use or allow digital devices in their lectures. Two other lecturers see no reason for using an iARS. And another two lecturers are short before their retirement.

7.3. Advanced survey evaluation

In addition to the descriptive results and basic evaluation in the chapter before, some aspects of the survey results are investigated further.

First the relation between the lecture size and the probability of considering using an iARS is investigated. The question is, if lecturers who have more students in their lecturers rather consider using an iARS in their lecturers?

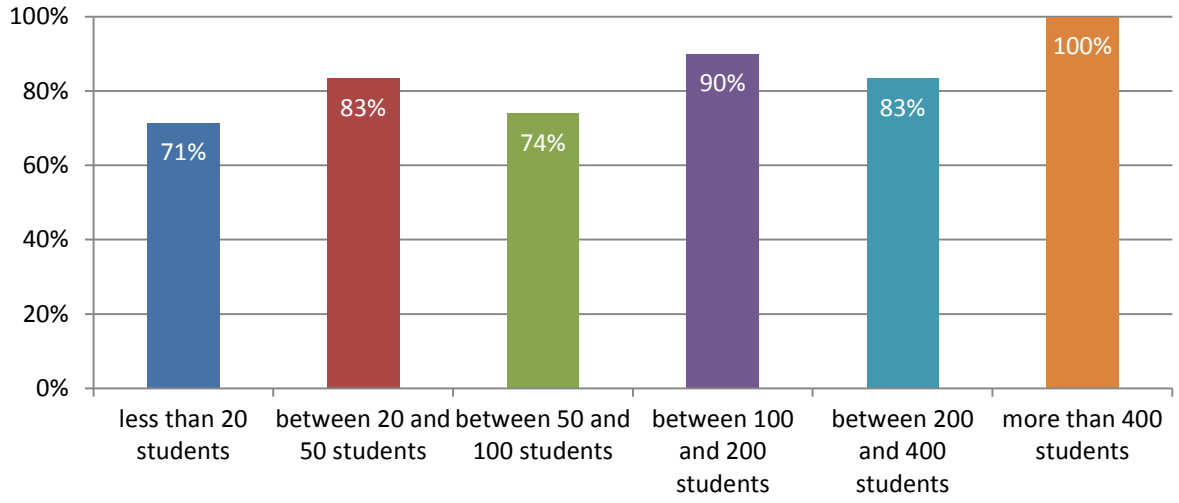


Figure 29: Evaluation of lecture survey results grouped by lecture sizes

The diagram in figure 29 shows how many lecturers would consider using an iARS in their next lectures, split by the maximum number of students they are teaching. As the diagram visualizes there is a trend that lecturers with more students in their classes tend to rather consider using an iARS. Because of the small sample sizes in the first and last group it would be over confidentially to answer the question with a strong yes, but there is a tendency to agree to the statement that lecturers with more students in their lectures would rather consider using an iARS.

Second the relation between the lecture field of the lecturers and the probability of considering using an iARS is investigated. The question is, if lecturers of different fields have different perceptions towards using an iARS in their lecturers?

The diagram in figure 30 shows how many lecturers would consider using an iARS in their next lectures, split by their field of study. As the diagram visualizes, in the fields of architecture, civil engineering, chemistry and physics approximately two out of three lecturers would consider using an iARS in their lectures. In the study fields of electrical engineering, informatics, mathematics and mechanical engineering approximately 9 out of 10 would consider using an iARS in their lectures lecturers. Because of the small sample sizes in the fields of electrical engineering, mathematics and mechanical engineering with eight participants respectively, it would be over confidentially to make general assumptions to the different perceptions of the lecturers' according to their field of study.

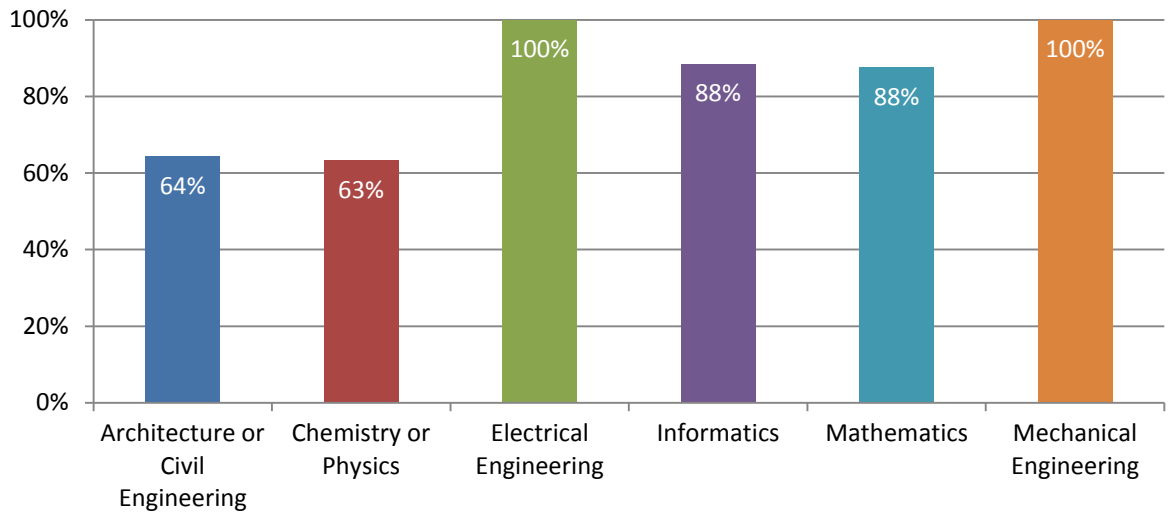


Figure 30: Evaluation of lecture survey results grouped by lecture fields

Third the relation between the different course types of the lecturers and the probability of considering using an iARS is investigated. The question is, if lecturers of who hold different course types have different perceptions towards using an iARS in their lecturers?

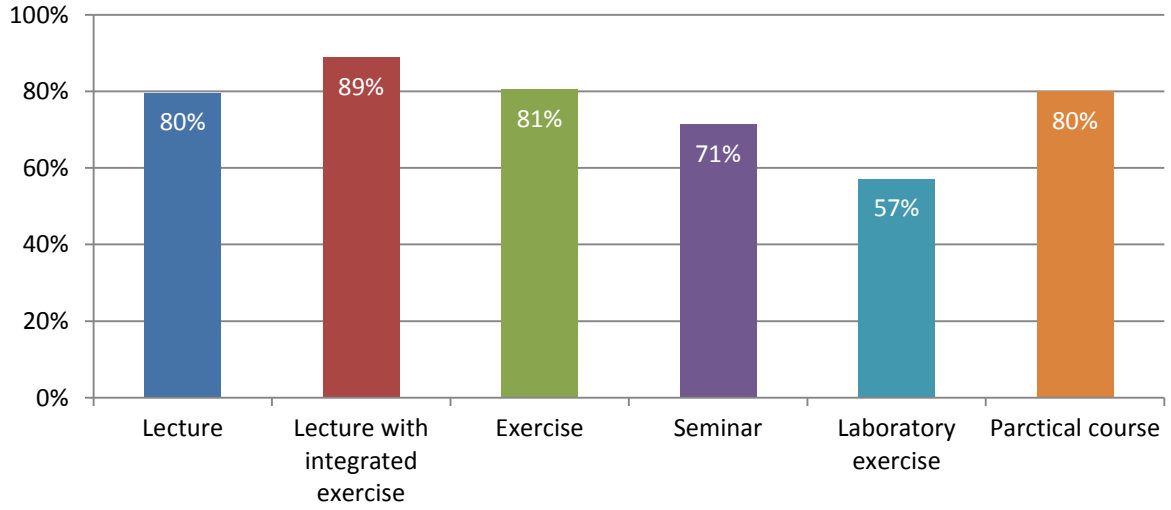


Figure 31: Evaluation of lecture survey results grouped by course types

The diagram in figure 31 shows how many lecturers would consider using an iARS in their next lectures, split by their types of courses. As the diagram visualizes, in the course type lecture with integrated exercise (also called VU) approximately 9 out of 10 lecturers would consider using an iARS in their lectures. 80% of the lecturers who hold a course with the type of lecture, exercise or practical course (only 5 data points) would consider using an iARS in their lectures. The course types seminar and laboratory exercise lag behind with 71% and 57% respectively. It can be stated that it is most likely that lecturers who hold the course types lecture, lecture with integrated exercise or exercise would rather consider using an iARS in their next lectures.

8. Discussion

In this chapter the results of the thesis are discussed. The research questions which are described in chapter 3 are answered and possible threads to the validity of the proposed assumptions are stated.

8.1. iARS requirements

Which requirements emerge for web-based iARS and which system design fulfils them in a large scale education environment?

The requirements for web-based integrated Audience Response Systems emerge through initial requirements from literature, expert discussion for the first prototype development and the pilot test of the first prototype. The requirements were elicited after an expert and can be grouped into 5 different categories i.e. requirements regarding the different interactive tasks, the interactive task type requirements, requirements regarding the managing of the presentation slides, post-processing requirements and technical requirements.

Table 24 shows the amount of requirements of the improved prototype in each category which emerged from references to the literature, the amount of requirements which were proposed for the development of the first and the improved prototype and how much requirements emerged in total. Combining the tables 18a to 18e provides the full list of all 36 requirements.

Requirement categories	From literature	From first and improved prototype development	Total
Interactive task requirements	6	5	11
Interactive task type requirements	3	1	4
Presentation slides requirements	5	5	10
Post-processing requirements	1	2	3
Technical requirements	2	6	8

Table 24: Requirement categories of the improved prototype

The requirements were evaluated through two prototypes which fulfil their respective requirements and which were evaluated in the pilot test in chapter 5.4 and the case study explained in chapter 6.3. Additionally the conducted lecturers' survey which is described in chapter 7 evaluated the demand for key requirements.

Another important point for Audience Response Systems in general is the selection of the interactive task types they will provide. An optimal interactive task type selection would select the types by a weighting between the type most of the lecturers will use during their lectures and the effort to design and implement the interactive task type into an integrated Audience Response System tool. As the first information was not a-priori available during the development of the first and improved prototype, the interactive task types were selected by their occurrences in the literature research cf. table 10. Within the lecturers' survey the participants were asked to state their estimation if they would use a specific interactive task type during their lectures. Figure 32 shows a graphical representation regarding the results of this question. The interactive task types are sorted from the

most popular to the least popular ones. Interactive task types marked with a * are currently provided by the developed improved prototype. As shown in the diagram the top three interactive task types are already implemented in the improved prototype.

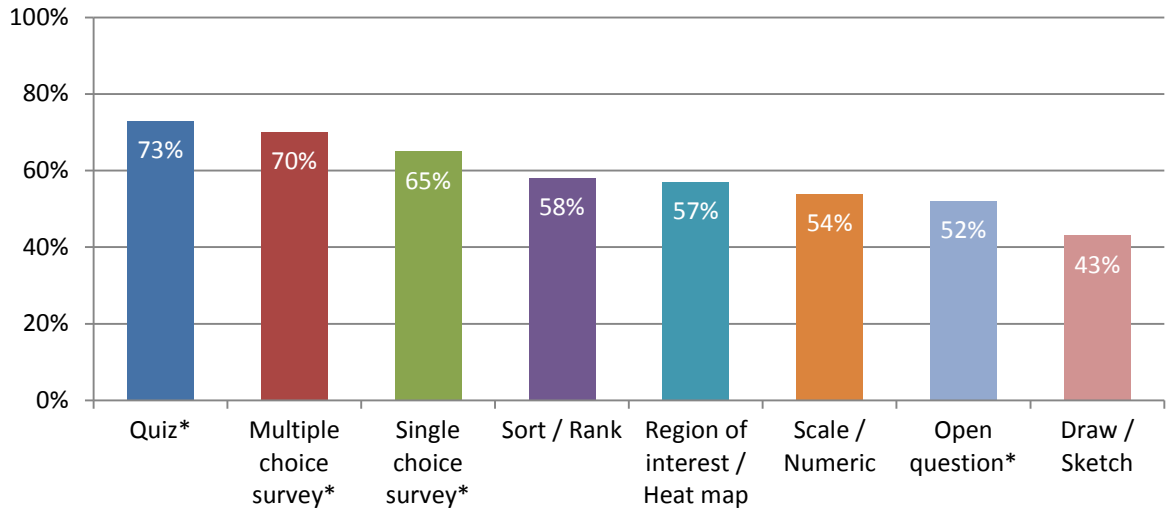


Figure 32: Results of lecture survey interactive task types

Beside the requirements of integrated Audience Response Systems the design of a system that fulfils these requirements was a topic of the research question. To answer this part of the research question two prototypes were developed within an iterative software development process [Boehm, 1988, p. 64]. To design the architecture of the first prototypes a value-based approach cf. [Biffl, Aurum, Boehm, Erdogmus, & Grünbacher, 2006] was applied. After the architecture had been evaluated in the pilot test, discovered restrictions and shortcomings of the architecture design were stated. Then an improved architecture was developed, the outcome of this improvement process is visualized in figure 17. The improved architecture design was evaluated during the case study, where it was successfully deployed in 14 different lecture units. Additionally the workflow of the prototype, which is part of the system design, is visualized in figure 18.

8.2. iARS prototype evaluation

Which methods are suitable to evaluate web-based iARS prototypes in a large scale education environment?

To assess which methods are suitable for an evaluation of an integrated Audience Response System prototype, different methods had been deployed. During the pilot test of the first prototype and the case study of the improved prototype the following data collection methods were applied. Every applied data collection method can be classified as direct method, where the researcher is in direct contact with the subjects and collects data in real time. This classification is based on the data collection technique levels defined by [Lethbridge, Sim, & Singer, 2005, p. 313]. The results of the data collection methods are summarized in chapter 5.4 and chapter 6.3.

The evaluation method observation was applied during the deployment of the first prototype in the pilot test and during the deployment of the improved prototype in each lecture unit of the case study. According to the categorization schema proposed by [Runeson & Höst, 2009, p. 147] the

observation can be categorized between case 3 and case 4 observations. The characteristics of a case 3 observation is that there is only a low interaction by the researcher during the units of analysis and the subjects have a high awareness of being observed by the researcher. While in case 4 the subjects have only a low awareness of being observed by the researcher cf. [Runeson & Höst, 2009]. During the lectures the lecturer was aware that he/she was observed by the researchers. The researchers were present to observe the deployment of the prototypes and delivered support in case of blocking technical problems. The students had only a low awareness of being observed by the researchers, because the prototypes were handled by the lecturer or an assistant of the lecturer and the researchers were seated in the audience of the lecture and behaved most of the time like a normal student attending the lecture. Therefore the applied observation method for an integrated Audience Response System prototype was a combination of case 3 and 4 of the categorization schema defined by [Runeson & Höst, 2009, p. 147].

The second data collection method used was the direct feedback provided by lecturers and students after a lecture of the pilot test or case study. The method of collecting these feedbacks was through unstructured interviews. The classification as unstructured feedback, as described by [Robson, 2002], means that the questions of the interview were not planned in advance, instead the conversion was able to evolve based on the interests and concerns of the subjects, in case of the prototype evaluations, the lecturers and students. The researcher had only a guideline of focus areas for the interviews, e.g. if a problem was mentioned did it emerge because of the setup of the subject, a fault in the system, a not considered use case or weakness in the system design.

The third data collection method used was the indirect feedback provided by students through a feedback function in the first and improved prototype. The feedback has been given in written form before, during and after a lecture of the pilot test or case study. The location of the feedback function in the user interface of the students can be found in each screenshot of the first and improved prototype, e.g. in figure 13. The method can be categorized as a survey with only one question and without an invitation to participate.

The fourth data collection method used was a survey conducted once per lecture course at the end of a lecture unit. It was only applied during the case study of the improved prototype. The survey was deployed as paper questionnaire and the students were invited to participate after the lecture had ended. The sampling strategy used was self-selection sampling; the students could self-decide if they participate within the survey or not. For the design of the survey the scientific literature was consulted cf. [Fowler Jr, 2013] and [Kitchenham, et al., 2002].

During the pilot test and case study the evaluation methods observation, direct feedback and the survey of the student's delivered an utilizable amount of data and a good data quality. This leaded to valuable results for the evaluation of the requirements and the system design. In contrast the evaluation approach through the feedback function in the prototypes delivered only two utilizable responses from the students during the pilot test and case study.

Therefore it can be stated that for the evaluation of iARS or ARS tools in general a combination of qualitative data collection and quantitative data collection is suitable and required. This leads to a methodical triangulation of the gathered data which increases the precision of the empirical evaluation approach.

It is proposed that the lecturers should be investigated with qualitative evaluation approaches, to gather in depth insights about the requirements they impose at an integrated Audience Response System tool. The lecturers are an important target group, because of their main role within Audience Response Systems; they have to introduce, prepare, use and evaluate it and therefore are critical for a successful deployment of such a tool.

It is proposed that the students should be investigated with quantitative and qualitative evaluation approaches. The quantitative approach serves to collect the perception of the students in large

education environments towards specific topics of interest, e.g. the willingness to reuse the tool. Qualitative approaches should be used to gain additional insights into specific problems or concerns and to think outside the box which is constructed with quantitative approaches.

8.3. iARS lecturers survey

Which insights can be gained from currently established lecture processes and is there a demand for an iARS in university education?

To answer this research question a survey addressing all lecturers at the Vienna University of Technology was conducted. The survey was designed with help of the guidelines stated in “Principles of Survey Research Part 2: Designing a Survey” [Kitchenham, 2002], “Principles of Survey Research Part 3: Constructing a Survey Instrument” [Kitchenham & Pfleeger, 2002] and “Survey research methods” [Fowler Jr, 2013].

102 persons participated in the survey, 100 of them had stated that they are lecturers on a university. 97 participants are holding lectures at the Vienna University of Technology. The answer data analysis showed a good data quality with a good data mix which is not biased towards a specific study field, junior or senior lecturers, a type of lectures or the size of a lecture. The complete data quality evaluation is described in chapter 7.2.1.

During the survey the lecturers answered question in different topics of interest. Some requirements of an interactive Audience Response System were additionally evaluated through the survey. For example 67% of the participants would use the combined export function, where the presentation slides and the results of the interactive tasks get bundled into one PDF file. The requirements which were additionally evaluated through the survey are described in the chapter 7.2.4 and 7.2.5.

Another section of the survey investigates the current lecture preparation process and another one the current presentation style of the lecturers. The results indicated that 92% of the lecturers who participated prepare digital presentation slides for their lectures. 97% of the lecturers use digital support, e.g. a projector device or a laptop, during their lectures. 43% of the lecturers solely present their presentation slides with presentation software, the rest of the lecturers present their presentation slides directly from a PDF file.

The experience with Audience Response Systems was very low, only 9 of the lecturers had used an Audience Response System in one of their past lectures. However 5 out of these 9 lecturers had used the prototypes, which were developed as part of this thesis, during the conducted pilot test and case study. Therefore only 4% of the lecturers that participated in the survey would have used an Audience Response Systems in one of their lectures if the prototypes would not have been deployed.

The results of the survey regarding the demand for an integrated Audience Response System tool are very promising. First 88% of the lecturers would invest at least 30 minutes to get trained or train themselves with a new Audience Response System tool. Second 82% of the lecturers would consider using an integrated Audience Response System in their future lectures. This proves a high demand for a well-developed integrated Audience Response System tool in university education context.

8.4. Threats to validity

Possible threads to validity of the results emerge from different sides. First the evaluation of the requirements and the system design through the pilot test and case study were conducted at the Vienna University of Technology. Additionally the complete pilot test and 4 out of the 5 lecture courses of the case study were part of the curriculum of informatics and therefore were mainly attended by informatics students. Therefore the evaluation of the first research question could be biased towards engineering education or in particular towards the education of informatics.

For the conducted students survey during the case study of the improved prototype the sampling strategy self-selection had been used. This implies the risk that an unrepresentative subset of the population, which consists of students that attended the lecture, had been surveyed. Although it was not noticeable for the researcher that for example only students that had used the prototype during the lecture participated in the survey, a risk remains.

Because the lecture survey was only distributed to all lecturers at the Vienna University of Technology, it is presumable that the results are biased towards the lecturer population of Vienna University of Technology. The chosen sampling strategy was self-selection, i.e. each lecturer could decide for her-/him-self if she/he would participate in the survey. This implies the risk that an unrepresentative subset of the population, which consists of all lecturers at the Vienna University of Technology, had been surveyed.

9. Summary and future work

In this thesis different aspects of integrated Audience Response Systems were investigated. The first topics of analysis included the requirements that emerge for a web-based integrated Audience Response System and a system design which fulfils the emerging requirements, see chapter 3.1. Second suitable evaluation methods for iARS prototypes were investigated, see chapter 3.2, and third the demand for integrated Audience Response System tools was analyzed, see chapter 3.3. All topics were discussed and evaluated in the context of large scale education environments.

To assess this questions a literature research was conducted to find already proposed requirements for traditional Audience Response Systems, see chapter 2.1. Beside requirements the literature research analyzes the interactive task types that were implemented in the investigated ARS tools, see chapter 2.2. Additionally the conducted evaluation methods of the implemented ARS tools were investigated during the literature research, see chapter 2.3. The requirements of the literature got summarized and grouped into different categories. After requirements that were not relevant for the development of a web-based integrated Audience Response System were cleaned out, they formed the basis for the next step, see chapter 5.1.

The requirements were extended, discussed and condensed with experts resulting in 19 requirements for the development of a first prototype, see chapter 5.2. The system design, including the architecture and workflow, was developed and implemented during a prototype development, see chapter 5.3. The prototype was evaluated in a pilot test, in which the prototype was deployed in seven real-world lecture units. During the pilot test three different evaluation methods were used to collect data about the prototype deployment, see chapter 5.4. The collected data was used to propose new requirements for the development of an improved prototype.

Another expert discussion was conducted to state the requirements for the second prototype development. As result 36 requirements categorized into 5 different groups were stated, see chapter 6.1. The architecture and workflow of the first prototype were revised according to the newly stated requirements. After the requirements and the system design were developed, an improved prototype was implemented, see chapter 6.2.The improved prototype was evaluated in context of a case study. In the case study the improved prototype was deployed during 14 lecture units in 5 different lecture courses. In addition to the three evaluation methods of the pilot test a survey for the students was conducted in the lecture units where the improved prototype was deployed.

The results of the student survey, in which 247 students had participated, were very positive; 87% of the students found the deployment of the improved prototype during the lecture useful or rather useful. 74% of the students would agree or rather agree that the deployment was beneficial for their understanding of the lecture material. 91% of the students would use the integrated Audience Response System tool again in other lectures. The evaluation of the distraction potential such a tool could induce resulted that only 12% of the students were distracted or rather distracted from the lecture by the use of the improved prototype, see chapter 6.3.

To gain additional insights into the currently established lecture processes and to assess the demand for integrated Audience Response Systems in university education a survey for the lecturers was conducted. All lecturers at the Vienna University of Technology were invited to participate in the survey, see chapter 7.1. The results of the survey, in which 100 university lecturers had participated, were very promising. The survey delivered detailed information about currently used lecture processes. 92% of the lecturers prepare digital presentation slides for their lectures. 97% of the lecturers use digital support, e.g. a projector device or a laptop, during their lectures. 43% of the lecturers solely present their presentation slides with presentation software, the rest of the lecturers present their presentation slides directly from a PDF file.

Additionally the survey evaluated the past experience of the lecturers with ARS tools and investigated the willingness to use an integrated Audience Response tool. Only 4 % of the lecturers had experience with Audience Reponses Systems during their lectures, beside the experience with the developed prototypes. 82% of the lecturers would consider using an integrated Audience Response System in their future lectures, see chapter 7.2.

For future work a third iteration cycle of the prototype development can be conducted. While the improved prototype successfully mitigated the main problems of the first prototype, there is still room for improvement. A start point could be the data gathered during the case study of the improved prototype, through observation and direct feedback of the lecturers and students. The acquired data is summarized in chapter, see chapter 6.3.

Further work could be applied to overcome the threads to validity of the results as stated in chapter 8.3. The prototype could be deployed in different universities to mitigate the risk of being biased towards engineering education. The lecturer survey could be conducted on different universities to formulate a general statement about the demand for integrated Audience Response Systems in large scale education environments.

Bibliography

Abramson, D., Pietroszek, K., Chinaei, L., Lank, E., & Terry, M. (2013). Classroom response systems in higher education: Meeting user needs with NetClick. *Global Engineering Education Conference (EDUCON), 2013 IEEE*, (pp. 840-846).

Akaslan, D., Law, E. L., & Taskin, S. (2012). Analysis of issues for implementing e-learning: The student perspective. *Global Engineering Education Conference (EDUCON), 2012 IEEE*, (pp. 1-9).

Avdic, A., Grönberg, P., Olsson, J., & Guerra Riveros, F. (2014). Development of a Real-time Formative Feedback Student Response System. *Journal of Network and Innovative Computing, 2*(1), 259-268.

Ayu, M. A., Taylor, K., & Mantoro, T. (2009). Active learning: Engaging students in the classroom using mobile phones. *IEEE Symposium on Industrial Electronics Applications, 2009. ISIEA 2009.*, *2*, pp. 711-715.

Bakrania, S. (2012). A study on the influence of rich versus traditional classroom response system (CRS) questions on concept retention. *Frontiers in Education Conference (FIE), 2012*, (pp. 1-6).

Baqer, M., & Kamal, A. (2009). ACRS: An Advanced Classroom Response System Architecture for Learning Enhancement. *Second International Conference on Developments in eSystems Engineering (DESE), 2009*, (pp. 287-291).

Beatty, I. D., Leonard, W. J., Gerace, W. J., & Dufresne, R. J. (2006). Question driven instruction: Teaching science (well) with an Audience Response System. *Audience response systems in higher education: Applications and cases*.

Bele, J. L., Bele, D., Hauptman, S., & Debevc, M. (2014). eCampus as a platform for ubiquitous learning. *Global Engineering Education Conference (EDUCON), 2014 IEEE*, (pp. 1-7).

Biffl, S., Aurum, A., Boehm, B., Erdogmus, H., & Grünbacher, P. (2006). *Value-based software engineering.* Springer Science & Business Media.

Blasco-Arcas, L., Buil, I., Hernandez-Ortega, B., & Sese, F. J. (2013). Using clickers in class. The role of interactivity, active collaborative learning and engagement in learning performance. *Computers & Education, 62*, 102-110.

Boehm, B. W. (1988). A spiral model of software development and enhancement. *Computer, 21*(5), 61-72.

Böttcher, A., Kämper, A., & Thurner, V. (2015). On feedback techniques for the evaluation of teaching effectiveness. *Global Engineering Education Conference (EDUCON), 2015 IEEE*, (pp. 668-675).

Caeiro-Rodriguez, M., Gonzalez-Tato, J., & Llamas-Nistal, M. (2013). Experiencing a Web-based Audience Response System in engineering lectures. *Global Engineering Education Conference (EDUCON), 2013 IEEE*, (pp. 513-519).

Cagiltay, N. E., Aydin, E., & Kara, A. (2010). Principles for the design of a remote laboratory: A case study on ERRL. *Education Engineering (EDUCON), 2010 IEEE*, 879-884.

Caldwell, J. E. (2007). Clickers in the large classroom: Current research and best-practice tips. *CBE-Life Sciences Education, 6*(1), 9-20.

Clark, C. (1989). *Brainstorming: How to Create Successful Ideas.* Wilshire Book Company.

Clauson, K. A., Alkhateeb, F. M., & Singh-Franco, D. (2012). Concurrent use of an audience response system at a multi-campus college of pharmacy. *American journal of pharmaceutical education, 76*(1), 6.

Dahlstrom, E., Brooks, D. C., Grajek, S., & Reeves, J. (2015). *ECAR Study of Students and Information Technology, 2015.* Louisville, CO: ECAR.

Fies, C., & Marshall, J. (2006). Classroom response systems: A review of the literature. *Journal of Science Education and Technology, 15*(1), 101-109.

Fowler Jr, F. J. (2013). *Survey research methods.* Sage publications.

Freeman, J., & Dobbie, A. (2005). Use of an audience response system to augment interactive learning. *Fam Med, 37*(1), 12-4.

Freeman, M., Bell, A., Comerton-Forde, C., Pickering, J., & Blayney, P. (2007). Factors affecting educational innovation with in class electronic response systems. *Australasian Journal of Educational Technology, 23*(2), 149.

Fuad, M. M., Deb, D., & Etim, J. (2014). An evidence based learning and teaching strategy for computer science classrooms and its extension into a mobile classroom response system. *14th International Conference on Advanced Learning Technologies (ICALT), 2014 IEEE*, (pp. 149-153).

Gauci, S. A., Dantas, A. M., Williams, D. A., & Kemm, R. E. (2009). Promoting student-centered active learning in lectures with a personal response system. *Advances in Physiology Education, 33*(1), 60-71.

Haintz, C., Pichler, K., & Ebner, M. (2014). Developing a Web-Based Question-Driven Audience Response System Supporting BYOD. *J. UCS, 20*(1), 39-56.

Han, J. H. (2014). Closing the Missing Links and Opening the Relationships among the Factors: A Literature Review on the Use of Clicker Technology Using the 3P Model. *Educational Technology & Society, 17*(4), 150-168.

Hatziapostolou, T., Pupovci, T., Dranidis, D., Paraskakis, I., & Ntika, M. (2014). Boosting the Pedagogical Value of Classroom Clicker Systems via the Provision of Formative Feedback. *14th International Conference on Advanced Learning Technologies (ICALT), 2014 IEEE* , (pp. 165-167).

Jagar, M., Petrovic, J., & Pale, P. (2012). Auress: The audience response system. *ELMAR, 2012 Proceedings*, 171-174.

Karakostas, A., Adam, D., Kioutsiouki, D., & Demetriadis, S. (2014). A pilot study of QuizIt: The new android classroom response system. *International Conference on Interactive Mobile Communication Technologies and Learning (IMCL), 2014*, (pp. 147-151).

Kay, R. H., & LeSage, A. (2009). Examining the benefits and challenges of using audience response systems: A review of the literature. *Computers & Education, 53*(3), 819-827.

Kay, R., LeSage, A., & Knaack, L. (2010). Examining the use of audience response systems in secondary school classrooms: A formative analysis. *Journal of Interactive Learning Research, 21*(3), 343-365.

Kitchenham, B. A. (2002). Principles of Survey Research Part 2: Designing a Survey. *ACM SIGSOFT Software Engineering Notes, 27*(1), 18.

Kitchenham, B. A., & Pfleeger, S. L. (2002). Principles of Survey Research Part 3: Constructing a Survey Instrument. *ACM SIGSOFT Software Engineering Notes, 27*(2), 20-24.

Kitchenham, B. A., Pfleeger, S. L., Pickard, L. M., Jones, P. W., Hoaglin, D. C., El Emam, K., et al. (2002). Preliminary guidelines for empirical research in software engineering. *IEEE Transactions on Software Engineering, 28*(8), 721-734.

Klimova, B., & Poulova, P. (2015). Mobile learning and its potential for engineering education. *Global Engineering Education Conference (EDUCON), 2015 IEEE*, (pp. 47-51).

Krasner, G. E., & Pope, S. T. (1988). A description of the model-view-controller user interface paradigm in the smalltalk-80 system. *Journal of object oriented programming, 1*(3), 26-49.

Lam, S. L., Wong, K., Mohan, J., Xu, D., & Lam, P. (2011). Classroom communication on mobile phones--first experiences with web-based 'clicker'system. *ASCILITE-Australian Society for Computers in Learning in Tertiary Education Annual Conference*, *2011*, pp. 763-777.

Lethbridge, T. C., Sim, S. E., & Singer, J. (2005). Studying software engineers: Data collection techniques for software field studies. *Empirical software engineering, 10*(3), 311-341.

Llamas-Nistal, M., Caeiro-Rodriguez, M., & Gonzalez-Tato, J. (2012). Web-based audience response system using the educational platform called BeA. *International Symposium on Computers in Education (SIIE), 2012*, (pp. 1-6).

Lowry, P. B., Romano Jr, N. C., & Guthrie, R. (2006). Explaining and predicting outcomes of large classrooms using audience response systems. *Proceedings of the 39th Annual Hawaii International Conference on System Sciences, 2006. HICSS'06.*, *1*, p. 4c.

Lucke, T., Keyssner, U., & Dunn, P. (2013). The use of a classroom response system to more effectively flip the classroom. *Frontiers in Education Conference, 2013 IEEE*, (pp. 491-495).

Mantoro, T., Ayu, M. A., Habul, E., & Khasanah, A. U. (2010). Survnvote: A free web based audience response system to support interactivity in the classroom. *Conference on Open Systems (ICOS), 2010 IEEE*, (pp. 34-39).

Mateo, Z. F. (2010). Creating active learning in a large introductory statistics class using Clicker technology. *Proceedings of the 8th International Conference on Teaching Statistics.* Ljubljana, Slovenia.

McLoone, S. C., O'Keeffe, S., & Villing, R. (2013). Design, implementation and evaluation of a tablet-based student response system for an engineering classroom. *24th IET Irish Signals and Systems Conference (ISSC 2013)*, (pp. 1-7).

Moen, R., & Norman, C. (2006). Evolution of the PDCA cycle.

Moral, M., Javier, F., & de Marcos Ortega, L. (2014). Perceptions and attitudes toward Interactive Whiteboards and Classroom Response Systems. *6th International Conference on Adaptive Science & Technology (ICAST), 2014 IEEE*, (pp. 1-5).

Robson, C. (2002). *Real world research. 2nd Edition.* Blackwell Publishing.

Runeson, P., & Höst, M. (2009). Guidelines for conducting and reporting case study research in software engineering. *Empirical software engineering, 14*(2), 131-164.

Silliman, S. E., & McWilliams, L. (2004). Observations on Benefits/Limitations of an Audience Response System. *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition.*

Stowell, J. R., & Nelson, J. M. (2007). Benefits of electronic audience response systems on student participation, learning, and emotion. *Teaching of psychology, 34*(4), 253-258.

Turban, J. W. (2011). Students Prefer Audience Response System for Lecture Evaluation. *iJET, 6*(4), 52-55.

Yin, R. K. (2013). *Case study research: Design and methods.* Sage publications.

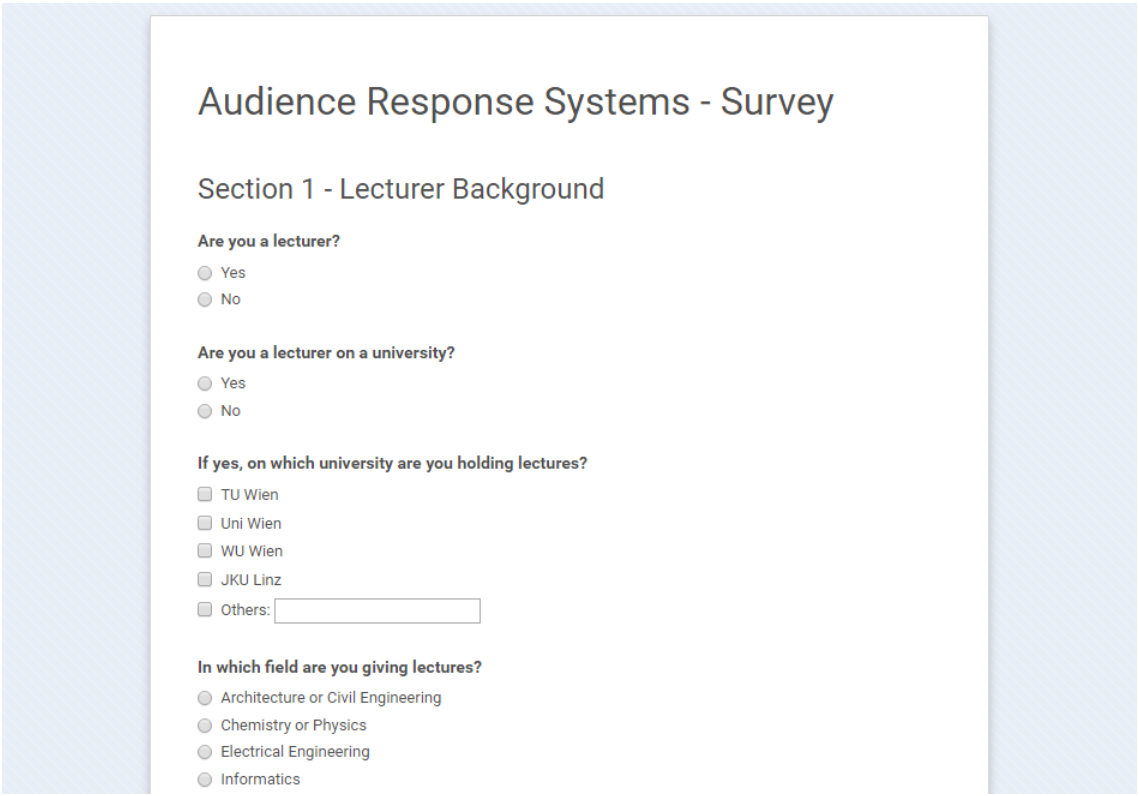
List of Figures

List of Tables

Appendix

A1. Lecturers survey questions

Two screenshots are visualizing the design and layout of the lecturers' survey.



Audience Response Systems - Survey

Section 1 - Lecturer Background

Are you a lecturer?

- Yes
- No

Are you a lecturer on a university?

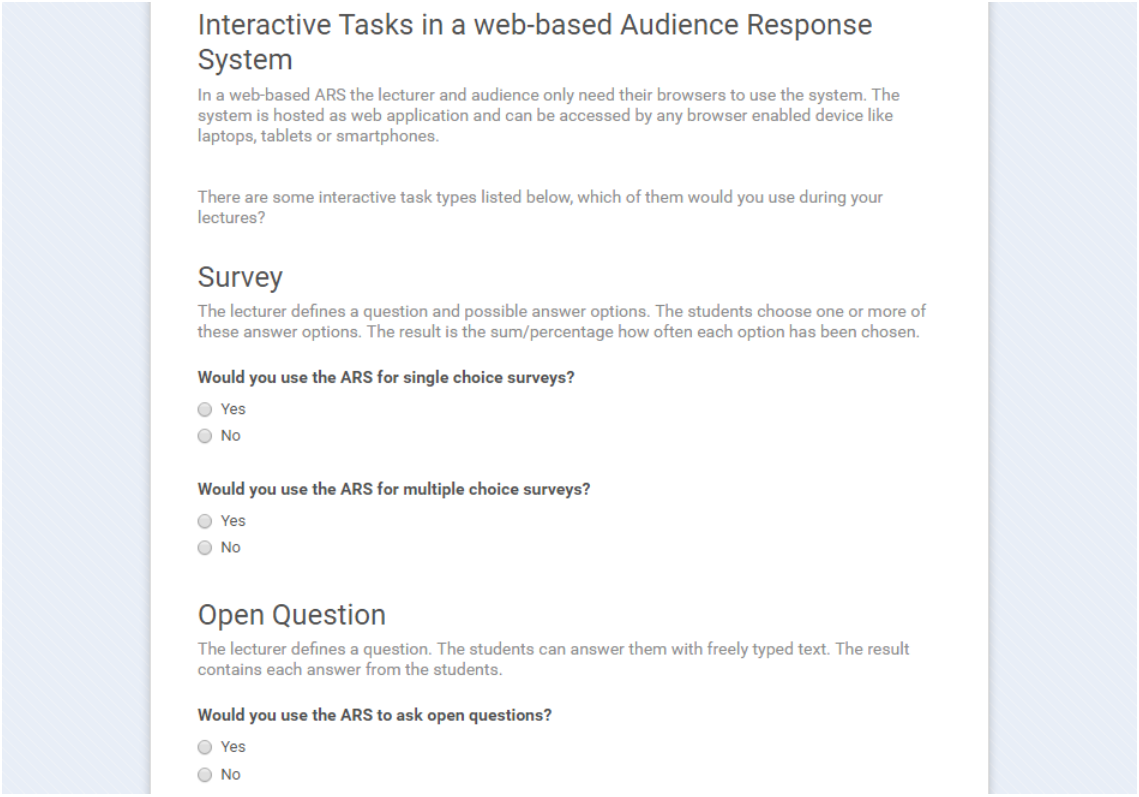
- Yes
- No

If yes, on which university are you holding lectures?

- TU Wien
- Uni Wien
- WU Wien
- JKU Linz
- Others:

In which field are you giving lectures?

- Architecture or Civil Engineering
- Chemistry or Physics
- Electrical Engineering
- Informatics



Interactive Tasks in a web-based Audience Response System

In a web-based ARS the lecturer and audience only need their browsers to use the system. The system is hosted as web application and can be accessed by any browser enabled device like laptops, tablets or smartphones.

There are some interactive task types listed below, which of them would you use during your lectures?

Survey

The lecturer defines a question and possible answer options. The students choose one or more of these answer options. The result is the sum/percentage how often each option has been chosen.

Would you use the ARS for single choice surveys?

- Yes
- No

Would you use the ARS for multiple choice surveys?

- Yes
- No

Open Question

The lecturer defines a question. The students can answer them with freely typed text. The result contains each answer from the students.

Would you use the ARS to ask open questions?

- Yes
- No

Below the complete text of the lecturers' survey is provided.

Section 0 – Introduction Text	
As part of my master thesis, supervised by Prof. Stefan Biffl from the Information & Software Engineering Group and supported by the Teaching Support Center of TU Wien, we investigate the requirements and the design of Audience Response Systems in university environments. Audience or Classroom Response Systems are tools for activating students in lectures with a high number of participants. The main use case is providing an active feedback channel from the audience to the lecturer. As example for an interactive task the lecturer can prepare questions, ask them to the students during the lecture, collect their answers through the Audience Response System (ARS), present and discuss the results with the students. To evaluate the needs and find new requirements for an ARS in university context, a survey for lecturers is conducted. The survey collects data about the current lecturer preparation and presentation processes, experiences with ARS, the need for different interactive tasks, requirements for an ARS and willingness to use an ARS. Your participation at the survey will be anonymously and treated with strictest confidentiality. No personal information will be published and the data will only be used in scope of the mentioned thesis. If you have any questions about this survey, would like to get more information about Audience Response Systems or would like to test an ARS in one of your next lecturers, please contact me patric.prasch@tuwien.ac.at	

Section 1 – Lecturer Background	
Are you a lecturer?	yes, no
Are you a lecturer on a university?	yes, no
If yes, on which university are you holding lectures?	[MC] TU Wien, Uni Wien, WU Wien, JKU Linz, Others
In which field are you giving lectures?	Architecture or Civil Engineering, Chemistry or Physics, Electrical Engineering, Informatics, Mathematics, Mechanical Engineering, non-technical field, Others
How long are you holding lectures on universities?	[Range] less than 1 year, between 1 year and 4 years, between 5 and 9 years, between 10 and 19 years, more than 20 years
How many courses are you holding next semester (summer term 2016)?	no courses, 1 course, 2 courses, 3 courses, >3 courses, >5 courses
What type of courses are you holding?	[MC] VO (lecture), VU (lecture with integrated exercise), UE (exercise), Others

What is the maximum number of students attending one of your courses?	[Range] less than 20 students, between 20 and 50 students, between 50 and 100 students, between 100 and 200 students, between 200 and 400 students, more than 400 students

Section 2 – Lecture Preparation	
Do you prepare digital presentation slides to support your lectures?	yes, no
If yes, which tools are you use to prepare your slides?	[MC] PowerPoint, Keynote, GoogleSlides, LaTeX, Others
Do you prepare additional notes and comments for individual slides?	yes, no
Do you export your presentation slides as PDF for your presentation?	yes, no
Do you provide your presentation slides to your students before the lectures?	yes, no
How often do you update slides from previous courses?	Never, every two years, every year, every semester, before the lecture, continuously during the semester
How much effort do you need on average to update these slides for a single lecture unit?	[Range] Slides normally need no update, less than 15 minutes, between 15 and 30 minutes, between 30 minutes and 1 hour, between 1 hour and 4 hours, between 4 hours and 1 day, more than 1 day

Section 3 – Presentation Style	
Do you use any supporting equipment during your lecture?	yes, no
Do you use digital presentation support during your lectures?	[MC] Laptop, Tablet, Beamer, Others
Do you use presentation software during your lecture? (This question is not about how you generate your presentation slides)	[MC] PowerPoint, Keynote, Google Slides, presenting PDF directly, Others
How do you control your presentation during your lectures?	[MC] directly on laptop/tablet, wireless mouse, wireless pointer/presenter device, Others
Do you use any (additional) analog tools during your lectures?	[MC] Blackboard, Whiteboard, Flipchart, Overhead Projector, Others
Do your lectures have interactive elements?	[MC] small exercises, surveys, questions with discussion, Others
How much time do you spend with interactive elements during your lectures in percent?	[Range] 0%, between 1 and 10%, between 10 and 25%, between 25 and 33%, between 33 and 50%, more than 50%
Post-processing	
Do you provide your presentation slides to your students after the lectures?	yes, no
Do you provide the additional notes and comments (if any) to your students?	yes, no
Is there any difference between presented and provided slides?	yes, no

Section 4 – Using an Audience Response System	
Audience or Classroom Response Systems are tools for activating students in lectures with a high number of participants. The main use case is providing an active feedback channel from the audience to the lecturer. As example for an interactive task the lecturer can prepare questions, ask them to the students during the lecture, collect their answers through the Audience Response System (ARS) and show and discuss the results with the students.	
Did you use a Classroom or Audience Response System (ARS) in your past lectures?	yes, no
If yes, which one (name, commercial or self-developed)?	[MC] Socrative, FreeQuizDome, Feedbackr, i>clicker, Presentr, Others
If yes, why did you select this specific ARS?	open
Interactive Tasks in a web-based Audience Response System	
In a web-based ARS the lecturer and audience only need their browsers to use the system. The system is hosted as web application and can be accessed by any browser enabled device like laptops, tablets or smartphones.	
There are some interactive task types listed below, which of them would you use during your lectures?	
Survey	
The lecturer defines a question and possible answer options. The students choose one or more of these answer options. The result is the sum/percentage how often each option has been chosen.	
Would you use the ARS for single choice surveys?	yes, no
Would you use the ARS for multiple choice surveys?	yes, no
Open Question	
The lecturer defines a question. The students can answer them with freely typed text. The result contains each answer from the students.	
Would you use the ARS to ask open questions?	yes, no
How should students answer open questions via the ARS?	Anonymously, Personalized, Depends on question, Others
If the students can rate the answers of each other, would you allow it?	yes, no
Scale	
The lecturer defines a question and a scale, like 1 to 10. The students choose a number in the scale. The result is the average of the chosen numbers.	
Would you use the Scale interactive task?	yes, no
Sort/Rank	
The lecturer defines a question and answer items. The students rank the predefined items in their own order. The result is how many students have each item on which rank. A Question could be: Sort the following items in your order of importance.	
Would you use the Sort/Rank interactive task?	yes, no

Draw/Sketch	
The lecturer defines an exercise. The students solve it with a drawing. The result contains each drawing from the students.	
Would you use the Draw/Sketch interactive task?	yes, no
Quiz	
The lecturer defines a question, possible answer options and the correct answer set. The students choose one or more of the answer options. The result is the percentage between correct and false answers.	
Would you use the Quiz interactive task?	yes, no
Heat map / Region of Interest	
The lecturer prepares a specific presentation slide. The students click on a position within this slide. The result is a heat map where the clicks of the students get visualized. Possible usages could be fault finding in a model or clicking on formulas that are not understood.	
Would you use the Heatmap interactive task?	yes, no
Which alternative interactive tasks would be helpful in context of your lecture and student tasks?	open
Results from interactive tasks	
Would you present the results of the interactive tasks during your lectures (fast feedback)?	yes, no
Would you present good answers from the last semesters during the lecture?	yes, no
Integrate presentation slides within an Audience Response System	
In this ARS the lecturer additionally uses the system to present her/his presentation slides. The lecturer uploads their presentation slides to the integrated ARS before the lecture and presents them through the system. As controlling the presentation slides and the interaction methods is covered within one system the lecturer have to interact only with one software tool during the lecture.	
Would you prefer controlling your presentation slides and interactive tasks with one tool?	yes, no
Would you plan response methods at specific points in your presentation, e.g. at slide x?	yes, no
Would you use a feature, where students can see the presentation slides on their devices and automatically follow the current slide of the speaker (follow-me mode)?	yes, no
Are there any additional features you are missing or shortcomings of a possibly used ARS?	open

Section 5 – Administration of an Audience Response System	
If the system can identify each student with his/her student account, would you use the ARS to check the attendance of the students?	yes, no
Would you use the active participation of a student in an interactive task as part of his/her grading?	yes, no
Would you export the results of the interactive tasks for further processing?	yes, no
If, yes to which application/format would you export the data?	[MC] Spreadsheet (like Excel), XML or JSON, HTML, PDF, Others
Would you provide students access to the results of the interactive tasks after the lecture?	yes, no
Would you use a function, where your presentation slides and the results of the interactive tasks get bundled and exported into one PDF?	yes, no
Would you use a function to copy your interactive tasks (questions for the students) from a lecture last semester to a lecture this semester?	yes, no
What other functions for managing an ARS would you expect?	open

Section 6 – Introduce an Audience Response System	
How much effort would you invest to get trained / train yourself with a new Audience Response System?	[range] no additional effort, less than 15 minutes, between 15 and 30 minutes, between 30 minutes and 1 hour, between 1 hour and 4 hours, more than 4 hours
How much effort would you invest in preparation to add interactive elements, within an ARS, to a single lecture?	[range] no additional effort, less than 15 minutes, between 15 and 30 minutes, between 30 minutes and 1 hour, between 1 hour and 4 hours, more than 4 hours
Can you consider using an ARS including the described features in your future lectures?	yes, no
If not, why?	open

Section 7 – Only one click away!	
Personal Details (optional)	
Name	open
Department	open
E-Mail	open
Do you want to be informed about the results of this survey via E-mail?	yes, no
Can we contact you if we have additional questions, about your experience and thoughts?	yes, no
Would you like to get more information about a web-based ARS developed at TU Vienna?	yes, no
Would you like to test a web based ARS in one of your lectures next semester?	yes, no
Final Remarks	open

A2. Students survey questionnaire

Classroom / **A**udience **R**esponse **S**ystem - Umfrage

Haben Sie, abgesehen von Presentr, schon einmal ein Classroom/Audience Response System benutzt?

○ Ja ○ Nein

Wenn ja, welches und in welcher Lehrveranstaltung?

Haben Sie Presentr heute benutzt um Antworten auf Fragen des Vortragenden zu geben?

○ Ja ○ Nein

Wenn nein, warum nicht?

Wenn ja:

Fanden Sie den Einsatz von Presentr in der heutigen Vorlesung sinnvoll?

○ Ja ○ Eher ja ○ Eher nein ○ Nein

Denken Sie, dass der Einsatz von Presentr Ihr Verständnis des Unterrichtsmaterials begünstigt hat?

○ Ja ○ Eher ja ○ Eher nein ○ Nein

Würden Sie Presentr auch in anderen Vorlesungen wieder verwenden?

○ Ja ○ Eher ja ○ Eher nein ○ Nein

Hat Sie die Benutzung Ihres Devices (Laptop/Tablet/Smartphone) vom Unterricht abgelenkt?

○ Ja ○ Eher ja ○ Eher nein ○ Nein

Hätten Sie ihr Device auch während der Vorlesung benutzt wenn Presentr heute nicht eingesetzt worden wäre?

○ Ja ○ Eher ja ○ Eher nein ○ Nein

Gab es Probleme bei der Eingabe ihrer Antworten in Presentr, wenn ja welche?

Gibt es Feedback welches Sie uns zu Presentr geben möchten, um das System zu verbessern?