FAKULTÄT FÜR INFORMATIK

DER TECHNISCHEN UNIVERSITÄT MÜNCHEN

A Teaching Methodology for Massive On Campus Courses

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A Teaching Methodology for Massive On Campus Courses

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To Reinhold

Abstract

Education has come a long way since the establishment of the first university, the automatization of book printing and the introduction of black boards. Due to different economic constrains however the teaching and education market is growing massively in the last decade, which in consequence requires new ways to support instructors and students alike. In Germany the first year university student population has grown by 89% between 1999 and 2017. Following this trend, new ways of knowledge transportation have been created in the last decade in form of Massive Open Online Courses (MOOCS). Also In-class interactions are being optimized by teaching methodologies like flipped classroom to get the most out of presence-hours for students. Still a large impact factor that remains is a large student to instructor ratio. This hardly allows lecture tailoring and individual supervision and support of students, especially in a heterogeneous student group. In this dissertation a new teaching methodology for MOCCS (Massive On Campus Courses) is introduced which is based on AMATI (Another Massive Teaching Instrument) and MOCCA (Massive On Campus Course Architecture). AMATI is a software framework which increases interaction in large scale classrooms with more than 1000 students by adapting different approaches from existing software solutions to create a one-to-one supervision experience. MOCCA describes a new teaching concept which provides the needed steps to adapt an existing Massive On Campus Course (MOCC) classroom setup to an interactive virtual one-to-one teaching solution. AMATI and MOCCA have been evaluated over a period of three years at the Technical University of Munich (TUM) during the course "Einführung in die Softwaretechnik" (EIST) which has proven to increase interaction by over 400%. In addition, we found statistical evidence that students that actively participate in-class are able to achieve better exam grade points.

Zusammenfassung

Die Lehre hat seit der Gründung der ersten Universität, der Automatisierung des Buchdrucks und der Einführung von Tafeln einen langen Weg zurückgelegt. Aufgrund unterschiedlicher wirtschaftlicher Faktoren wächst der Lehr- und Bildungsmarkt im letzten Jahrzehnt jedoch stark, was neue Wege zur Unterstützung von Lehrenden und Studierenden erfordert. In Bezug auf Deutschland ist zwischen 1999 und 2017 ein Studentenwachstum an Universitäten von 89% im ersten Studienjahr zu verzeichnen. Daher haben sich auch im letzten Jahrzehnt neue Wege des Wissenstransports in Form von MOOCS etabliert, und die Interaktionen innerhalb des Unterrichts wurde durch verschiedenste Unterrichtsmethoden wie beispielsweise *Flipped Classroom* so optimiert, dass die Präsenzzeit der Lernenden optimal genutzt werden kann. Ein großer Einflussfaktor, der nach wie vor besteht, ist das Verhältnis von Studenten zu Dozenten. Dieses oft hohe Betreuungsverhältnis ermöglicht selten eine angepasste Vorlesungsgestaltung an die Lernenden sowie eine individuelle Betreuung und Unterstützung der Studierenden, insbesondere in heterogenen Lerngruppen. In dieser Dissertation wird eine neue Lehrmethode die sogenannte virtuelle eins zu eins Lehre für Massive On Campus Courses (MOCCS) vorgestellt, welche auf AMATI (Another Massive Teaching Instrument) und MOCCA (Massive On Campus Course Architecture) basiert. AMATI ist ein Software-Framework, das die Interaktion in großen Klassenräumen verbessert, indem verschiedene Ansätze aus vorhandenen Softwarelösungen kombiniert werden, um ein virtuelles 1-1 Kommunikationsverhältnis zwischen Lehrenden und Lernenden zu etablieren. MOCCA beschreibt ein neues Unterrichtskonzept, das die erforderlichen Schritte zur Anpassung eines vorhandenen MOCCS auf eine interaktive virtuelle eins zu eins Unterrichtslösung beschreibt. Another Massive Teaching Instrument (AMATI) und Massive On Campus Course Architecture (MOCCA) wurden über einen Zeitraum von drei Jahren an der Technical University of Munich (TUM) im Rahmen der Vorlesung "Einführung in die Softwaretechnik" (EIST) evaluiert und die Resultate haben gezeigt, dass sich die Interaktion im Vergleich zu einem typischen Massive On Campus Course (MOCC), welcher als Lehrmethode *Direkte Instruktion* verwendet, um über 400% steigern lässt. Darüber hinaus haben wir statistische Nachweise gefunden, dass Studenten welche sich aktiv am Unterricht beteiligen, mehr Prüfungsnotenpunkte erzielen.

Acknowledgments

As this dissertation has been spanned over nearly six years, without the support of friends and family this work would not have been possible. Therefore I would like to credit and acknowledge everyone who contributed to make this work possible.

First, I want to thank Prof. Bernd Brügge. From the supervision of my master thesis to offering me a position at his department Bernd always showed me ways to excel myself. By incorporating me in teaching duties I was able to stick to the things I loved most about university - to teach. I am grateful for your guidance throughout the creation of this work. Without your support this dissertation would not have been possible. Thank you for your generosity and support even during certain hardships throughout the years as well as for your trust working independently on my research and while teaching several courses.

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Contents

Chapter 1

Introduction

Chinese Proverb

"A thousand teachers, a thousand methods"

According to Blooms taxonomy [Blo56] as seen in Figure 1.1 there are different phases to achieve certain learning outcomes. From remembering to understanding over applying, analysing, evaluating and finally creating there are many steps to be taken to transfer knowledge from one individual to another. While different learning methods can be mapped to certain areas of this taxonomy there are several key factors for knowledge transfer in education.

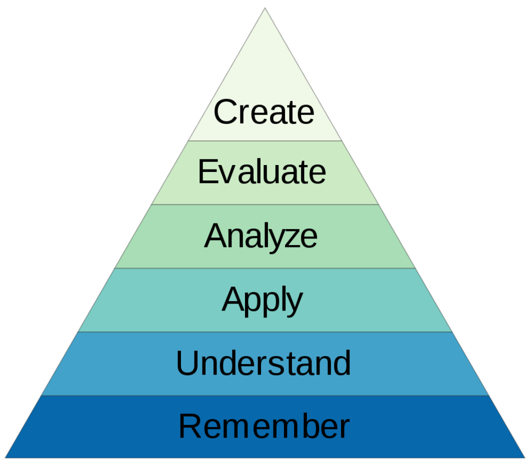

Figure 1.1: Blooms Taxonomy of educational learning, Graphic from Nicoguaro, Licence under CC BY 4.0

Those key factors start from lecture involvement [Mur+09] over student assessment [Sti94] to homework involvement [Coo+98]. To categorise and confine this thesis, a typical educational lecture can separated into three different areas, namely organisation, communication and assessment as seen in Figure 1.2.

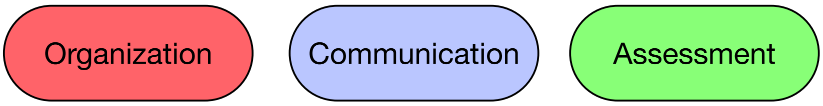

Figure 1.2: Categories of a typical lecture setup at universities

This thesis focuses on in-class interaction as a form of lecture involvement as part of the communication area by introducing Another Massive Teaching Instrument (AMATI), while the Massive On Campus Course Architecture (MOCCA) focuses on the organizational part, elaborating how to adapt an existing teaching concept to use AMATI successfully. This thesis contributes in the *understand* and *analyse* phases of blooms taxonomy, in the context of direct instruction in large scale audiences.

1.1 Problem Statement

At german universities, courses with more than 1600 students are no longer exceptional cases[1]. The first year student population in Germany has increased by 89% according to [Ger17] between the years 1998 - 2017. This increase has implications on class sizes and room availabilities and towards teaching personal.

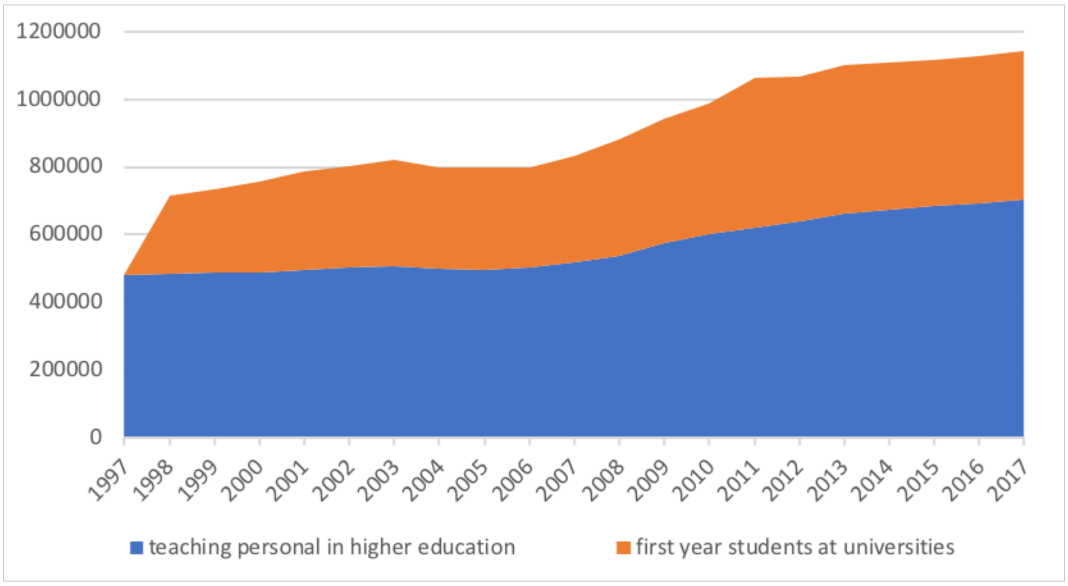

Figure 1.3: German first year university student population growth compared to higher education teaching personal growth between 1998 - 2017 based on [Ger17]

Comparing the german first year student population growth (89.77%) with the growth in teaching personal at higher education institutions (45.63%) we can see an increase

[1] `https://www.tum.de/en/about-tum/news/press-releases/short/article/33461/`

in the instructor to student ratio of (44.14%) as described in Figure 1.3. In contrast, the growth of german population (0.90%) stayed on a very neutral level as seen in Figure 1.4.

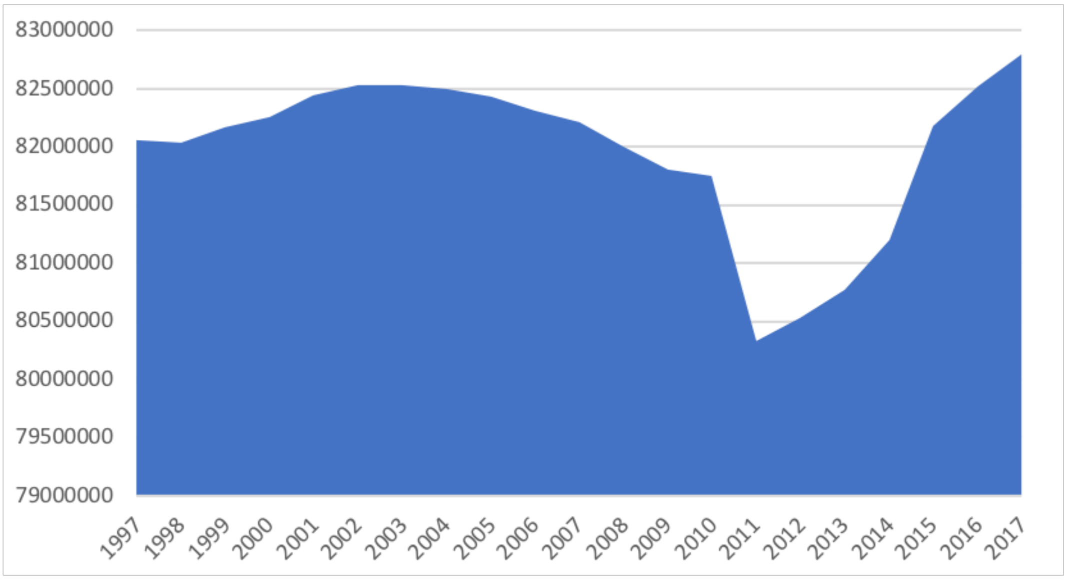

Figure 1.4: German population growth between 1998 - 2017 based on [Ger17]

All data presented is based on [Ger17] and the full data set can be found in Appendix 2. As an outcome of this steady growth in first year student population paired with a moderate growth of teaching personal, classroom sizes in universities increase each year as seen in Table 1.1 based on a software engineering foundation course held at the Technical University of Munich (TUM).

We define the result of those large scale classrooms as a Massive On Campus Course (MOCC).

> “ A MOCC is a course held on-campus using multiple classrooms for a single lecture applying live-streaming technologies to deliver teaching content to all participants at the same time but in different locations. ”

Even though student population has grown massively in the last decade, student population research has shown that the use of smaller class sizes has a positive effect on education performance. David Zyngier reviewed 112 papers written between the years 1979 - 2014 and found that small class sizes can have a lasting impact on student achievement, especially when combined with appropriate teacher pedagogies suited to reduced student numbers [Zyn14].

Lecture / year	# registered students
EIST 2016	1142
EIST 2017	1431
EIST 2018	1625

Table 1.1: Registered students for the EIST Lecture in the summer semesters 2016/2017/2018 in numbers

This aligns with findings from Bernard Bass who found a correlation between room size and their respective number of participants as well as the active participation of those participants as seen in Figure 1.5.[Bas79].

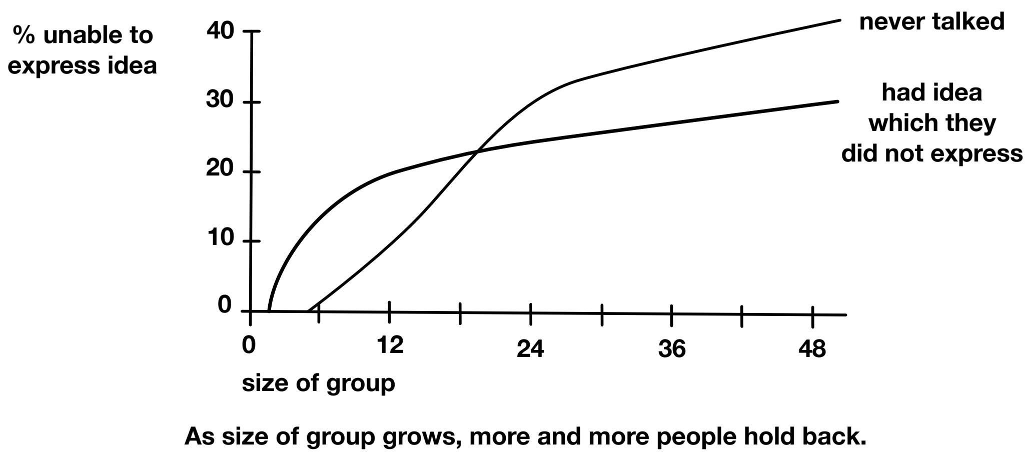

Figure 1.5: Participation depending on group size based on Berhard Bass [Bas79]

Still, one of the most used teaching methodologies in classrooms worldwide is direct instruction. As a result more learners do not interact with their instructor because of room sizes and other influencing factors which are described in Chapter 6.

1.2 Hypothesis

Using the participation rate formula from Berhard Bass [Bas79], doing a thought experiment with a classroom setup with 1400 participants, there would be 560 participants *(40 percent)* of the student population which would not be actively addressed at all. Concidering participants which would not express their thoughts, even if they had ideas or questions, 321 participants (30 percent) would rather prefer not to interrupt. Fritjof Kollmann [MS15] however showed that in a classroom of 321 students more than 80 percent of the student population actually want to actively participate. To bridge the gap between the desired student involvement and their actual involvement this dissertation introduces a new teaching approach named *virtual one-to-one* teaching. This approach is based on a dialectic interaction between teacher and student. We claim that this approach increases interaction and improves participation. We also claim that increased interaction can lead to improved knowledge transfer during a MOCC. In the following, we formalise these claims in two separate hypotheses HP1 and HP2.

HP1: Introducing digital communication to MOCCs increases the participation of students

By introducing new means of digital communication, we are able to engage students which would have not actively participated according to [Bas79]. This is achieved by lowering the barriers of interaction and re-establishing a very close communication paradigm in form of a dialectic approach between students and their instructors, while being scalable and fitting the demand of strongly increasing student numbers in higher education.

HP2: Increased interaction in Massive On Campus Courses (MOCCs) has a positive impact on student grade performance

By increasing interaction and communication in a large scale classroom using direct instruction and live-streaming, learners are able to achieve higher grade point averages if they actively participate during and after lecture hours.

1.3 Concept

The concept designed aims to bridge the gap between massive lectures (increase 89% of students in the last 15 years in Germany) and a personal teaching experience allowing students to actively participate in the classroom. To provide such a solution for large scale classrooms, we first examine existing teaching concepts which try to tackle communication problems in a mass teaching culture. Second, existing tool support for the presented teaching concepts are reviewed. Finally we provide a new teaching concept named MOCCA incorporating a new communication framework called AMATI to circumvent traditional barriers of interaction.

1.4 Contributions

In this dissertation we introduce a new teaching methodology enhancing traditional MOCCs with the following contributions.

C1

A software framework named AMATI to enable a virtual one-to-one communication including the delegation of teaching related questions to multiple moderators in real-time to reduce the *time-to-answer* for students. AMATI allows the creation of a *knowledge base* for students by introducing student reports as *knowledge item* sets for existing students questions. In addition, instructors are able to gain insights into questions related to their lecture material and are able to adapt lecture content based on students feedback.

C2

A *teaching methodology* named MOCCA which incorporates the virtual one-to-one teaching concept using a dialectic communication approach. MOCCA is able to deal with large student to instructor ratios common in MOCCs by implementing AMATI as in an interactive communication tool.

C3

An empirical evaluation of AMATI and MOCCA using a foundation software engineering course with a pool of 3500 students. This course has been designed for computer scientists and was evaluated at TUM over a period of three years.

1.5 Research Approach

For the research approach of this dissertation a formative approach was chosen which iteratively has refined the AMATI framework as well as the approach in transforming existing MOCCs using MOCCA. The research approach follows five different steps as described in Figure 1.6. The first step was the introduction of new means of communication during the Einführung in die Softwaretechnik (EIST) lecture in the summer semester 2016. Based on a result of a qualitative analysis, the means of communication have been restructured and redesigned. A second execution of the AMATI framework during the EIST course of the summer semester 2017 was evaluated qualitatively as well as quantitativly. Those results have been incorporated into the EIST course in the summer semester 2018, by introducing new features to AMATI.

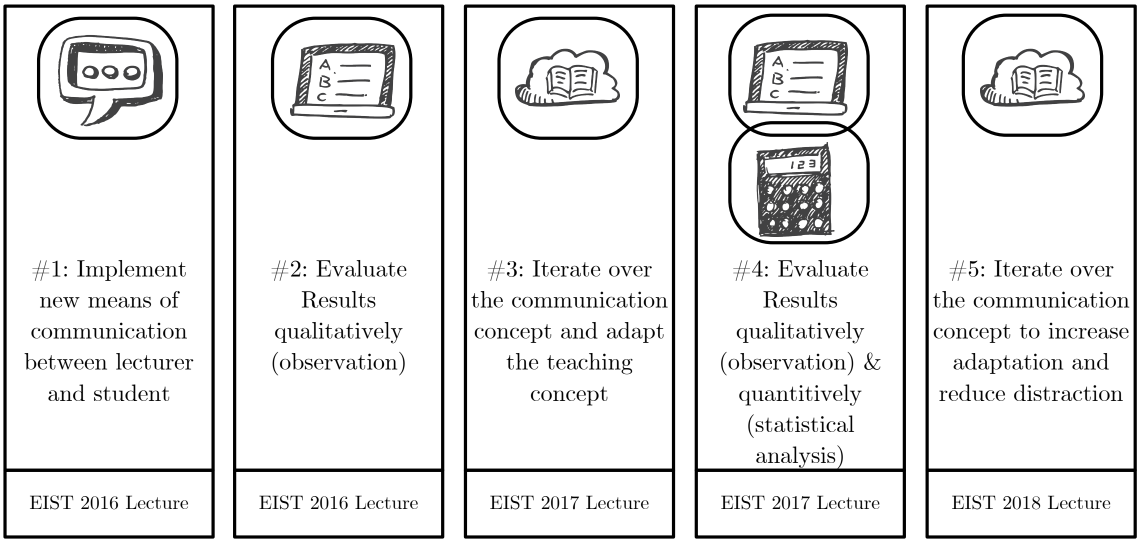

Figure 1.6: Research Approach: A formative and iterative design used on a software engineering foundation course

1.6 Dissertation Outline

This dissertation is structured in eleven chapters and is organized as follows:

Chapter 2 highlights the course of history in education with a focus on the teaching concepts used.

Chapter 3 elaborates existing learning theories combined with their applied learning methods, following up with advantages and disadvantages of the most prominent teaching models, concluding with the introduction of terminology for the MOCCA teaching model.

Chapter 4 introduces a new teaching concept named MOCCA. It describes the adaptations for typical classroom setups to transform Massive On Campus Courses into interactive classrooms. MOCCA creates a new teaching experience by adapting and combining teaching methodologies like peer instruction and active learning into a virtual one-to-one teaching approach. MOCCA can be seen as best-of-breed approach using existing teaching methodologies and concepts.

Chapter 5 reviews existing software tool support in education with focus on software engineering education and in-class communication. Based on the review of those existing tools, requirements are extracted for the implementation of AMATI.

Chapter 6 covers requirements for the AMATI software framework to support MOCCs as well as all the identified requirements to transform typical Massive On Campus Courses into interactive classrooms using MOCCA.

Chapter 7 and **Chapter 8** follow a systems engineering approach, covering the analysis and system design phase during the implementation of the AMATI software framework.

Chapter 9 describes the case-studies of the EIST course performed in the summer semesters of 2016, 2017 and 2018.

Chapter 10 describes our findings based on quantitative and qualitative analysis and concludes with threats to validity.

Chapter 11 summarizes the contributions and discusses aspects of future work.

The dissertation is based on on two publications of Jan Knobloch et al. presented at the Software Engineering in Education (SEET) track during the International Conference on Software Engineering (ICSE) conference in 2018 [KKB18] as well as proceedings of the Software Engineering im Unterricht der Hochschulen (SEUH) conference in 2017 [KG17].

Chapter 2
Teaching History

> Those who cannot remember the past are condemned to repeat it.
>
> George Santayana

Education and teaching methods have come a long way from early education until its actual counterparts in the 20th century. From the development of scripts and writing over more formal education in the middle ages up to compulsory education in most developed countries, many methods have been developed. Some pioneers in education have clearly been Socrates, Aristoteles and Plato. Important events have been the foundation of the first universities around 850 Before Christ (B.C), the invention of the first movable-type printing press by Johannes Gutenberg in 14th century as well as the creation of the first chalkboard in the 18th century. This chapter describes the history of education from its beginnings until today, highlights key aspects of each of the different eras and focuses on the most recent changes in our educational systems.

2.1 The Socratic Method

Socrates encouraged his students in an unending search for truth. His idea was an inductive approach by asking questions continuously until a contradiction to a first stated hypothesis has been reached. Some consider this approach as the so-called Socratic method. Aristotle wrote the following about his teacher Socrates in his metaphysic [Ari0 a].

> “For two things may be fairly ascribed to Socrates – inductive arguments and universal definition, both of which are concerned with the starting-point of science.
>
> *Aristotles* ”

Socrates was one of the first to apply an inductive approach, starting with a hypothesis and questioning it until eventually a contradiction has been found. One can clearly say that Socrates used discussions as a from of education. In addition, Socrates started defining general concepts which can be seen as definitions today. Also, the general concept of learning through experience has been recorded by Aristotle around 350 B.C. Aristotle wrote the following in his second Book of the Nichomachean Ethics [Ari0 b].

> “ For the things we have to learn before we can do them, we learn by doing them, e.g. men become builders by building and lyre-players by playing the lyre; so too we become just by doing just acts, temperate by doing temperate acts, brave by doing brave acts.
>
> *Aristotles* ”

This can be seen as one of the first descriptions to experiential learning. Building on the work of Socrates, Plato described a system for instruction that he claimed would lead to the ideal state. In *The Republic* [Pla0 a], Plato described a form of inquiry and debate to increase critical thinking and motivating ideas. It describes Platos views on building an ideal city which considers the ideal state of education in such a city. In the Republic, Plato also states that learning should be pleasurable to absorb knowledge.

> “ The true lover of learning then must from his earliest youth, as far as in him lies, desire all truth. ... He whose desires are drawn towards knowledge in every form will be absorbed in the pleasures of the soul. ”

However, the ability to read and possess reading material was sparse. Education was only available for higher classes of society. Knowledge was mainly transferred in private academies and monasteries. Due to the absence of books a lot of information was transferred orally by discussions in either dedicated schools or on public grounds when facilities where not available. This approach which can be seen as one of the first *one-to-one* teaching approaches where limited numbers of pupils where allowed to participate and teaching was a very personal experience.

2.2 From Monasteries to Gutenberg

Starting in 500 Anno Domini (A.D.), more institutions of education have been founded. In Europe, this movement was mainly based on christian principles in which churches and monasteries focused on a selection of latin learning and the art of writing. Meanwhile, one of the first continually operating and degree awarding educational institution was established in the year 859, the University of al-Qarawiyyin in Morocco[Pet+96]. It should take another 600 years when a breakthrough occurred in Europe with the invention of the first movable-type printing press by Johannes Gutenberg in the year 1454. This is often seen as one of the most critical aspects in starting the renaissance, the so called age of enlightenment as well as the scientific revolution.

2.3 Education during the Age of Enlightenment and Scientific revolution

During the renaissance, education started to spread its wings. Subjects now started to cover more than religious aspects and focussed also on greek and latin scripts which have been recovered and reprinted. This was also the birth of universities as we know them today. There were about 29 universities in the year 1400, 28 new ones were created in the 15th century, almost doubling the total. An additional 28 universities appeared between 1500 and 1625, leading to 73 universities in Europe.

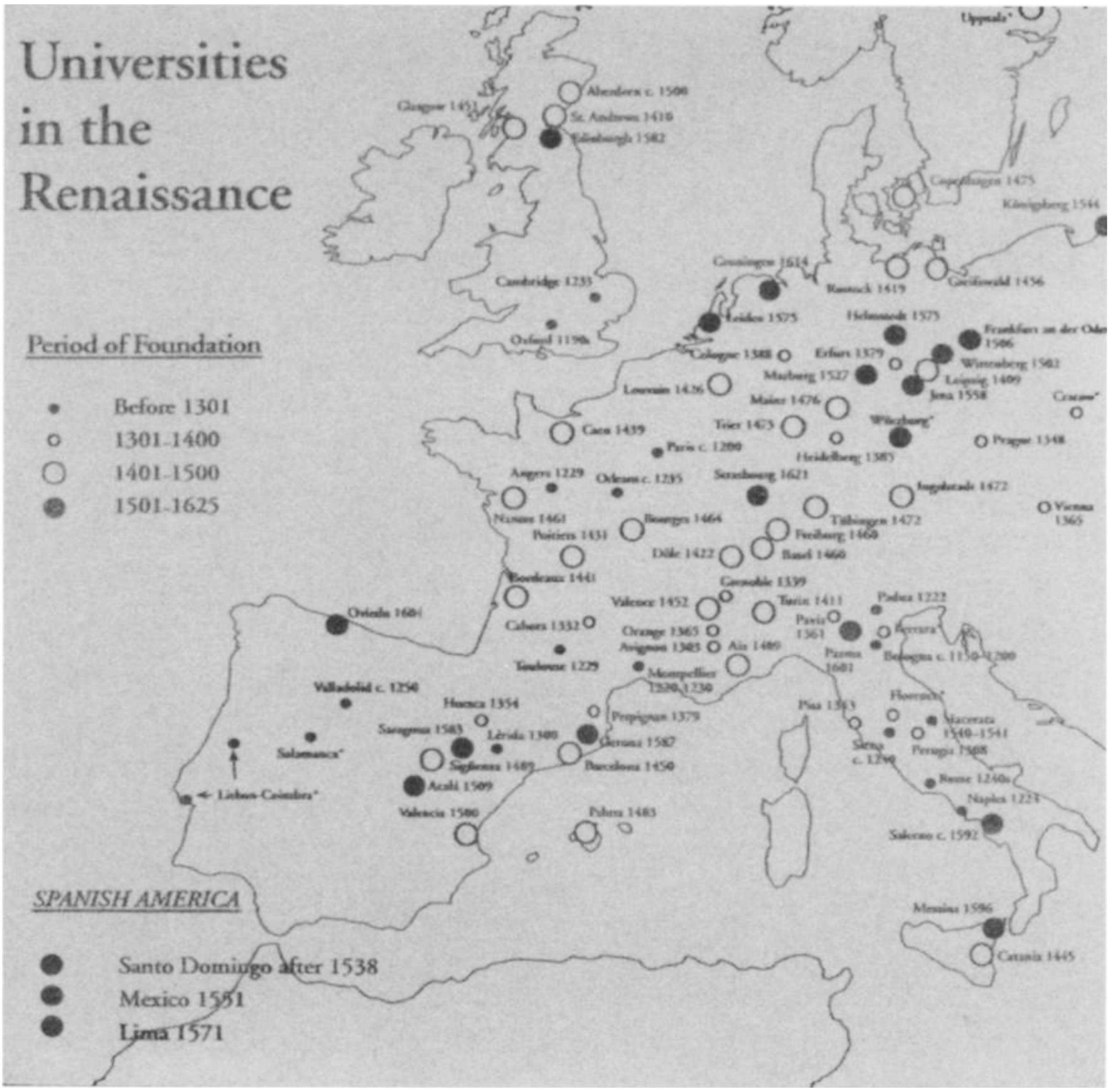

Figure 2.1: Universities during the Renaissance in 1625. Adapted from Encyclopedia of the Renaissance. Ed. Paul F. Grendler et al. 6 vols. New York, 1999, 6:190.

2.4 Education with slate boards

In 1801, James Pillans, a geography teacher from Scotland took an unusual teaching approach by introducing a blackboard to his teaching audience by mounting a large piece of slate onto a classroom wall [Ben15]. Since then, traditional teaching methods using slate boards have been described in letters as ”chalk and teach” methods [Mor19].

2.5 Interactive learning, Online courses and delegation

Considering how old education and teaching is, looking back at a history of over 2000 years, classrooms have barely changed with regards to their setup. Blackboards are still used today and students are still facing their instructors in a one-to-many scenario. It took until the end of the 19th century to realize that not every student can be treated in the same way. In the last forty years the desire for customized and tailored lecturing has grown stronger [Gar83]. Yet, economic circumstances formed the way teaching exists today. The economic needs dictate what is being taught, but not only that, it reflects even on how universities are designed. Many facilities of higher education operate in ways to fullfill the economic needs of cost and efficiency. According to Ken Robinson[1] this approach even leads to an inflation of academic degrees as more and more young people are being pushed into university education. This phenomenon leads to a so called *credential creep* which can be described as the process of inflation towards minimum job requirements. This raises the question on how we can find sustainable methods on dealing with large on campus courses. One way is the creation of so called Massive Open Online Courses (MOOCs)[Ada13] which can be produced very cost efficiently and allow students from all over the world to participate. Another way is to split classes and offer the same lecture multiple times at different locations and different times. Finally, teachers even start streaming teaching content in real-time to additional teaching halls to deal with the room constrains of very large classes. Considering those changes, new means of education have to be developed by analysing existing learning theories and learning methods which will be the topic of Chapter 3.

[1] `https://www.ted.com/talks/ken_robinson_says_schools_kill_creativity`

Chapter 3

Foundations

> If you do not know where you come from, then you don't know where you are, and if you don't know where you are, then you don't know where you're going. And if you don't know where you're going, you're probably going wrong.
>
> Terry Pratchett

This chapter covers the foundations of learning and teaching and consists of the major learning theories, learning methods and educational taxonomies.

In Section 3.1 multiple learning theories are introduced, starting with the traditional theories of Plato and Locke concluding with the most prominent learning theories in particular cognitivism, constructivism and behaviourism.

In Section 3.2 learning methods based on the provided learning theories of the previous section are introduced. Hereby the focus is on traditional concepts which are teacher-centred like direct instruction, central exercises or tutorials paired with student-centred approaches to create a more interactive classrooms in particular, active learning, experiential learning, flipped classroom, team teaching, peer instruction and a dialectic approach.

In Section 3.3 the Computer Supported Collaborate Work matrix and Edgar Dales Cone of Experience are illustrated to be able to categorise MOCCA as a teaching approach towards those taxonomies. In addition, an adapted reference frame is presented to classify all learning methods presented in Section 3.2 into their respective categories.

In Section 3.4 the main abstractions to MOCCA are introduced in form of a teaching model taxonomy which builds the base for the MOCCA teaching approach detailed in Chapter 4.

Due to the nature of this dissertation not all existing learning theories and methods can be covered but an excerpt of theories and methods reflecting the most prominent throughout education history are stated and provide a solid foundation to their use and adaptation towards this theses.

3.1 Learning Theories

Learning theories build the foundation of psychological, neurological and philosophical learning theorems in general. They often describe on how students are able to absorb, process and retain knowledge during their learning activities. These learning theories can be diverse and the following chapter highlights key aspects of some of the most influential representatives.

3.1.1 Plato and the Theory of Recollection

Plato describes his theory of recollection as the idea that all knowledge of an individual person is already present at birth and due to acquiring and gathering of new information a recollection or relinking of existing knowledge happens to retie information for further understanding. With this idea of Plato the following paradox can be formed:

> “ If a person knows something, they don’t need to question it, and if a person does not know something, they don’t know to question it.
>
> *Plato* ”

3.1.2 The Blank slate Theory

In contrast to Plato’s idea of the theory of recollection John Locke, states the theory of a so called "blank slate" in which humans are born with no innate knowledge. However individual humans have different "mental powers"[Loc00] which Locke pointed out to be the powers to collect experiences with given surroundings and store those memories and experiences what he defined as "slate". All of those experiences are growing together into complex and abstract ideas which help to understand certain concepts and even evolve new thoughts. This can be mapped to the idea of Subsection 3.2.5 in which students need to "experience" certain teaching concepts to fully understand them. This aligns with the definition of Karl Popper for the so called Tabula Rasa theory [Pop72] who states that scientific knowledge, stated in human language, is a separate entity that grows through critical selection into experiences to be stored by individuals.

3.1.3 Cognitivism

The Term Cognitivism grew out of the so called Gestalt psychology which was developed in the early 1900s by Max Wertheimer[Wer25], Wolfgang Köhler[Köh67] und Kurt Koffka[Kof14]. A typical phrase associated with the Gestalt psychology and therefore cognitivism is the sentence ”the whole is something else than the sum of its parts”. This statement states that the human mind is clever enough to interpret information in a way that are very specific to a single person and therefore not necessarily of interest for another person. Another example is the so called Necker cube [KB05] in highlighting the principle of the different cognitive states and interpretation of the human mind. In Figure 3.1 the Necker cube is highlighted which *switches* its appearance when inspecting it long enough.

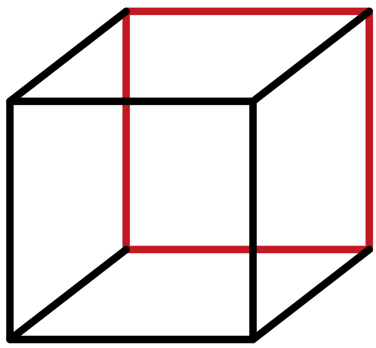

Figure 3.1: Necker Cube - Example of a Gestalt switch

This phenomenon is highlighted in Figure 3.2 as the red marked square changes its appearance depending on a human perception to be either at the back of the cube or at the top of the cube.
This is an example, on how individual learning experience can switch based on previous knowledge. Based on this unique perspective, each human has the ability generate different unique learning experiences and uses and interpret information in different ways to achieve certain learning goals.

3.1.4 Constructivism

Jean Piaget, the founder of constructivism emphasised the importance of active involvement of learners so they are able to construct knowledge for themselves [PC52].

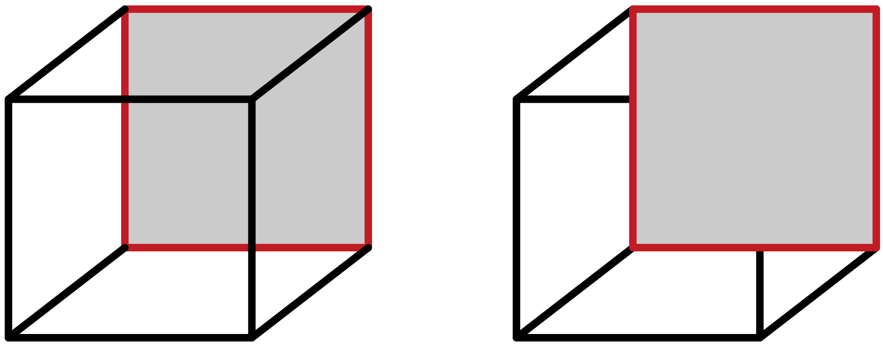

Figure 3.2: Necker Cube - Illustrated switch states

In contrast to typical chalk and talk teaching setups in which students receive all needed information in order to absorb knowledge, the idea of constructivism is to only provide background knowledge and concepts and then provide assistance in the acquisition of novel information. This should help to refine the cognitive structure provided by basic knowledge to refine and enrich it with novel information. Compared to typical chalk and talk teaching, constructivism expects from students not to learn all information by listening to a teacher, or reading from a textbook. Instead it is important for teachers to understand the common or basic level of students and based on this level start solving complex problems by introducing basic knowledge.

3.1.5 Behaviourism

The Beginning of Behaviourism, as a learning theory, can be traced back to Aristotle. Aristotle focused on the associations that can be made between different events such as lightning and thunder and described them in his essay *Memory*. Behaviourism therefore focuses on the study of behaviours or events that can be observed and measured. The basics of this theory follow the idea that the mind can be seen as a closed system which only responds to a stimulus which can be observed quantitatively without any thought processes occurring in the mind. In addition to the philosophers stated above, Ivan Pavlov and Burrhus Frederic Skinner investigated two types of conditioning, backing the concepts of behaviourism [Pav27],[Ski90],[Ski53],[Ski15]. John B. Watson [Wat13] tested stimulus-response procedures to evaluate classical conditioning on dogs by providing external stimulus when feeding the dog, and measuring a dogs reaction based on this external stimulus after iterations. Burrhus Frederic Skinner [Ski90] researched a technique known as operant conditioning in which the nature of consequences towards actions is measured and its potential effects on further decisions of subjects is analysed.

3.2 Learning Methods

Based on the previous Section 3.1 there are five major learning theories which build the foundation of many of the existing learning methods also used in university education today. Based on those learning theories there are more than than 50 different learning methods that exist today. To detail them all would be out of scope of this dissertation and this chapter focuses on the most relevant learning methods with regards to adaptation for AMATI and MOCCA. An extensive list of learning methods can be found in Appendix 1.

3.2.1 Direct instruction

Direct instruction after Siegfried Engelmann [Eng80] and Wesley C. Becker [Eng+88] is a general term of teaching certain skills by using lectures and a form of demonstration may it be the chalkboard or a more modern approach using presentation software and projectors. It denotes the communication between instructor and student is usually based on a monologue teacher-oriented design. Here the teacher often uses an *AnalogContentProviderItem* in the form of books or scripts or an *DigitalContent-ProviderItem* like a Powerpoint presentation. Bi-directional communication is often realized by interrupts of the existing monolog considering the assumption that the learners actually communicate their doubts or questions that arise on certain teaching topics. Other ways of communication are introduced by providing supported and unsupported exercises, including feedback and corrections.

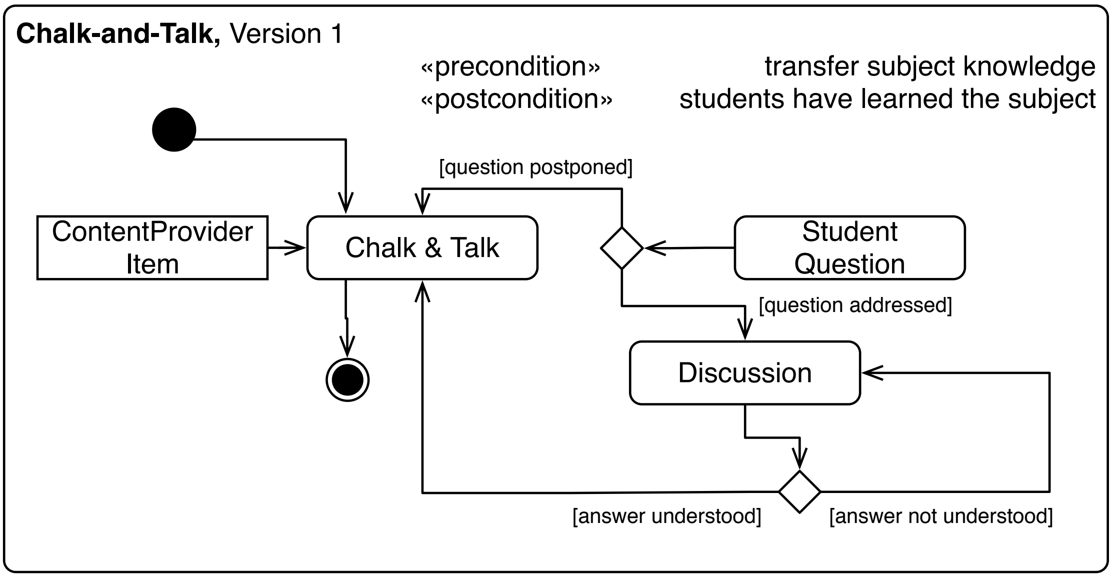

Figure 3.3: Direct instruction (UML Activity Diagram)

Using direct instruction usually forces a delay in the chalk and talk phase for each potential incoming student question that arises due to the nature of synchronous questions during lecture hours. Subsection 6.1.1 and Subsection 6.1.2 will provide more details regarding the concept of synchronous and asynchronous student questions, their individual impact on lecture suspension and their consequences for teaching personal.

3.2.2 Central exercises

Some teaching setups offer centralized exercises in addition to the chalk and talk teaching methodology. During these exercise hours the main goal is to enhance theoretical backgrounds taught through certain teaching material by backing it up with exercises or example calculations. This approach often differs from typical tutorial sessions as the ratio between instructor and students is still large. This reduces the possibilities for individual mentoring. A typical workflow to describe a centralized exercise which is similar to the direct instruction teaching method can be seen in Figure 3.4.

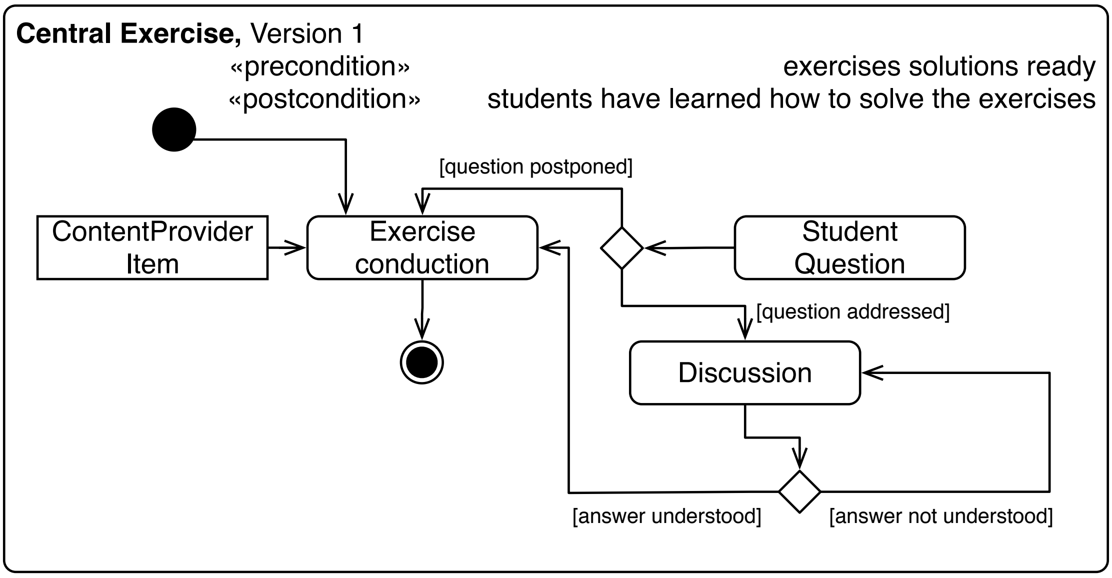

Figure 3.4: Centralized Exercise (UML Activity Diagram)

3.2.3 Tutorials

In comparison to centralized exercises, tutorials are reducing the ratio between teachers and students. The TUM aims for a typical ratio of one teacher to 25 students during tutorial sessions. Considering class sizes up to 1000 and more students this means there are at least 40 tutorial groups that need to be established and organized for a single course offered. This organizational efforts come with the benefit of creating a student centred approach. The idea of tutorials is to detail certain teaching aspects and allowing time for students to work together on solving exercises compared to a centralized exercise setup where the teacher presents solution methods, however is not able to address all individual student requests. Figure 3.5 highlights the key aspects to support individual students by parallelizing a typical student Q&A during exercise conduction. This is achieved by reducing the student to lecturer ratio, which allows for individual supervision under the assumption that not all students would like to phrase questions at the same time during the tutorial.

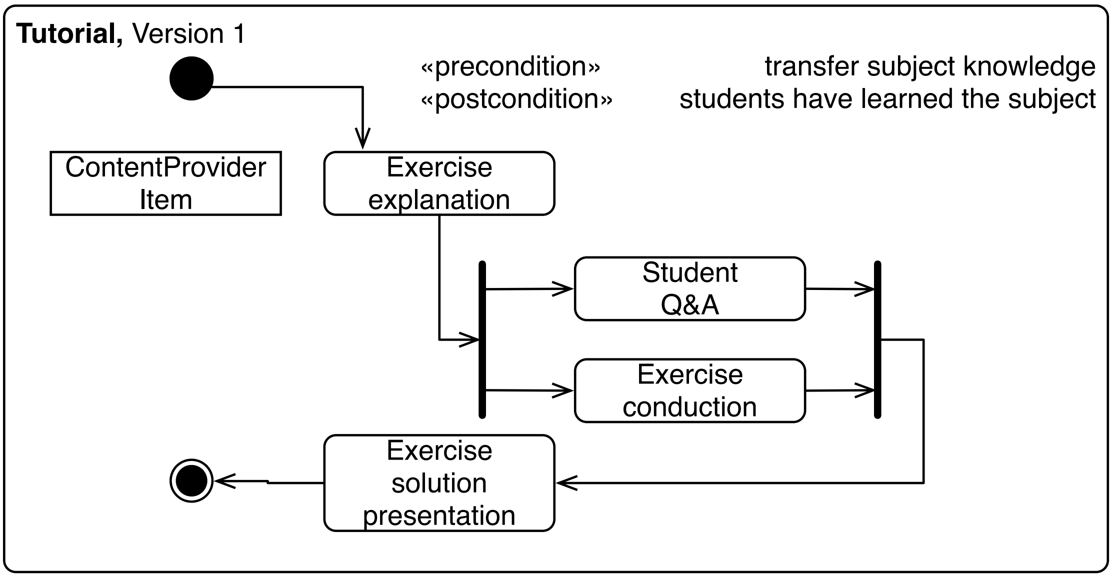

Figure 3.5: Tutorial (UML Activity Diagram)

3.2.4 Active Learning

Active learning is based on the principle to involve students in the learning process instead of having them be in the consumer role. According to Bonwell and Eison [BE91] students must do more than just listen to acquire knowledge. Furthermore students must read, write, discuss, or be engaged in solving problems.

3.2.5 Experiential learning

Experiential learning as a concept is an ancient approach stated by Aristotle in the Nicomachean Ethics [Ari0 b]. Aristotle wrote:

> “ For the things we have to learn before we can do them, we learn by doing them
>
> *Aristotles* ”

It took until 1974 in which David A. Kolb developed a modern theory of experiential learning described in [KRM74] and its impacts in [Kol14] are based on the work of Jean Piaget of the year 1952 [PC52]. The fundamentals kept, many activities and tasks are easier learned by doing them instead of watching or listening to explanations according to *experiental learning*.

3.2.6 Flipped Classroom

Flipped classroom as a learning method is based on blended learning principles which compared to direct instruction are not relying on teaching or demonstrating certain skills inside the classroom. A flipped classroom reverses activities which are usually done inside class by moving them outside the class. This allows more time in the class being dedicated to work on exercises, having discussions, collaborate with fellow students and answering questions with the guidance of a mentor. Many teachers and researchers can be credited with the invention of the flipped classroom as a single concept [BS12]. However, Jonathan Bergmann and Aaron Sams can be seen as originators of the principles behind this method. According to Carlos Turro [TMBM18], Paul Baepler [BWD14] and Clyde Herreid [HS13] flipped classrooms can have a positive impact on student performance, however also stating that the reduction of fewer students per square foot may be an impacting factor on those results. This aligns with Bernard Bass as described in Section 1.1 [Bas79]. The following Figure 3.6 depicts a typical flipped classroom workflow, starting with the knowledge acquisition at home and refining existing knowledge by Q&As or discussion sessions during class hours. Still there is no parallelism introduced regarding content delivery and discussion and refinement of knowledge.

3.2.7 Team Teaching

Team teaching is a learning method in which a single course makes use of two or more teachers. Those teachers share the creation, execution and assessment of students. Team teaching as a method is useful when different ways of explanation could prove helpful or if there are classroom projects which need the support of different domain

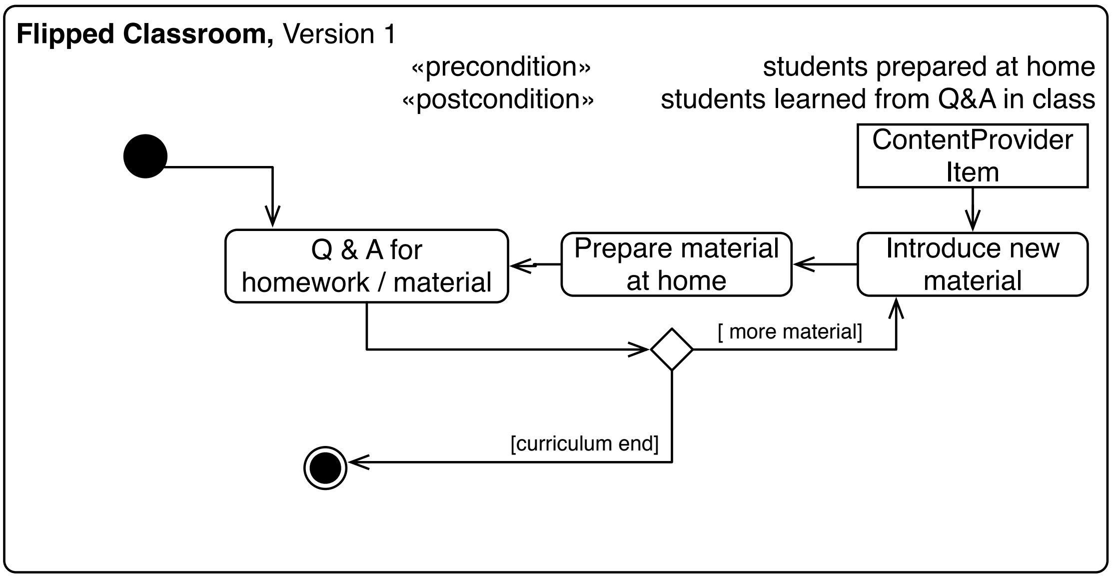

Figure 3.6: Flipped Classroom (UML Activity Diagram)

experts according to Francis Buckley [Buc99]. Typically, team teaching can be separated in two different phases namely an *exercise or application* phase and an *information* phase to elaborate new concepts and basic knowledge towards the material. According to Harold Davis [Dav66], team teaching assumes that the whole of the participants, working together, will have more impact on transferring knowledge and therefore will be a greater contribution to the classroom environment than a single participant working on his/her own. Team teaching is not considered to be a one fits all approach according to Donald Beggs [Beg64]. Therefore a team teaching setup needs to be evaluated and optimised for each individual course.

3.2.8 Peer Instruction

In 1997, Eric Mazur published his idea of peer instruction as a teaching method [MH97]. This *student-centered* approach is based on principles of a flipped classroom concept, however combining the different aspects of *direct instruction* with a flipped classroom and also in aspects of *active-learning* to allow students to exchange with their peers to acquire knowledge by discussion and critical thinking. In *Peer instruction* students therefore benefit from a *student-centered* approach based on the reduction of chalk and talk time during class hours. Figure 3.7 highlights the key aspect of *peer instruction* which incorporates student assessment during lecture hours. Based on student results of this executed assessment the lecture transforms in creating an interactive environment by either offering peer discussion, brief explanations or revised chalk-and-talk time based on the needs of the students to increase the students learning success.

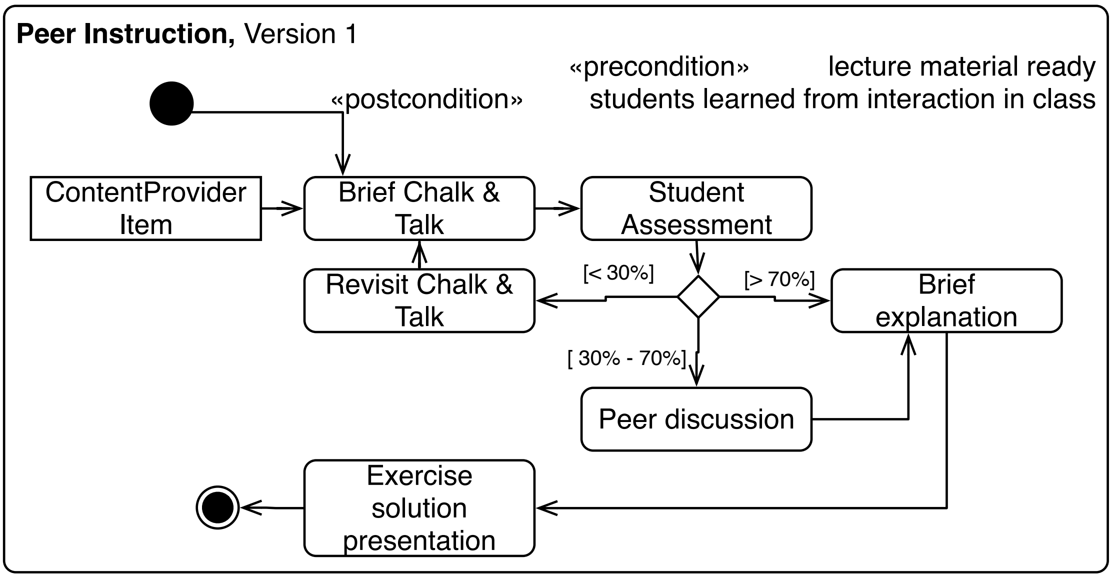

Figure 3.7: Peer instruction (UML Activity Diagram)

3.2.9 Dialectical Method

Socrates formulated a form of cooperative and argumentative dialog between individuals for the purpose of knowledge exchange. The idea of this concept is to allow critical thinking and exploring underlying ideas of certain concepts. John McPeck agrees and states that language, thinking and therefore learning are intimately tied together [McP16]. Phrasing questions to students but also from students to the instructor can therefore be seen as an important aspect to transfer knowledge till today, yet due to constrains of strong student to instructor ratios this concept is getting harder and harder to implement without technological support.

3.3 Learning Taxonomies

This section covers Computer Supported Cooperative Work (CSCW) and its matrix after Johansen [Joh88] in conjunction with the *Cone of Experience* after Edgar Dale[Dal70]. The two taxonomies are used in order to categorize the existing described learning methods and allow AMATI and MOCCA to be mapped to certain taxonomy definitions.

3.3.1 Computer Supported Collaborative Work

In 1984 the term CSCW was coined by Irene Greif und Paul Cashman while hosting a workshop with the name Computer Supported Cooperative Work [Gru94]. CSCW defines a interdisciplinary research area in which individuals in work groups or teams work together and are supported by information and communication technology. The goal of the research area is to analyze and optimize communication technology and group processes to increase their efficiency and effectivity. Based on this research field the so called CSCW-Matrix after Robert Johansen was formulated which is the first attempt to classify different CSCW approaches regarding the two dimensions, time and location as seen in Figure 3.8 [Joh88].

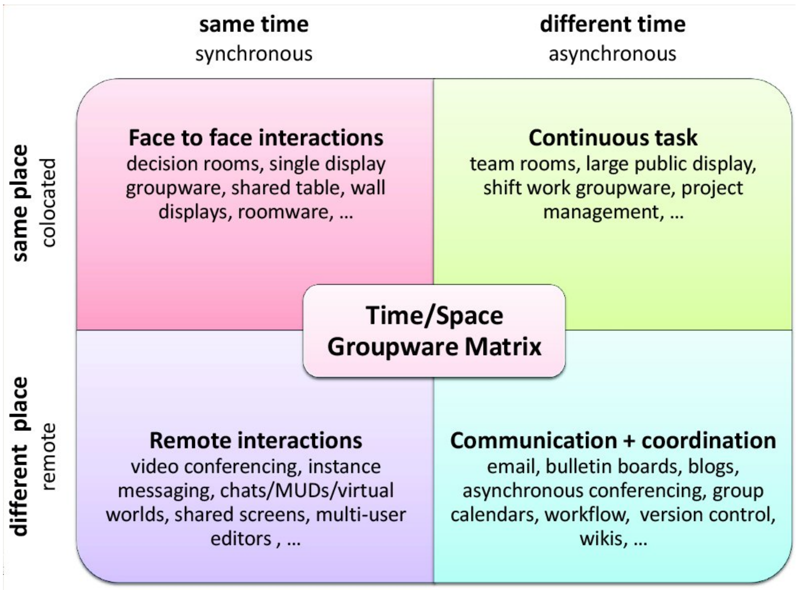

Figure 3.8: Computer Supported Cooperative Work Matrix based on Johansen [Joh88]

To classify this dissertation into the CSCW-Matrix the proposed solution of Another Massive Teaching Instrument (AMATI) and Massive On Campus Course Architecture (MOCCA) can be found in the same time (synchronous) but in both the same place (co-located) and different place (remote) area on the left of the matrix. Due to the nature of AMATI and MOCCA students are able to participate via classroom attendance or by using the provided live-stream of the lecture depending on their preference.

3.3.2 Cone of Experience

Edgar Dale proposed his *Cone of Experience* in the year 1946, highlighting that students achieve better learning results if they are not only focusing on what they read or hear. Based on this principle, it is important that students get the chance to not only consume content by watching and hearing. When students are able to execute and actively participate in the lecture it can be found they can are able to remember 70% of what they say and write, as seen in Figure 3.9. As the AMATI

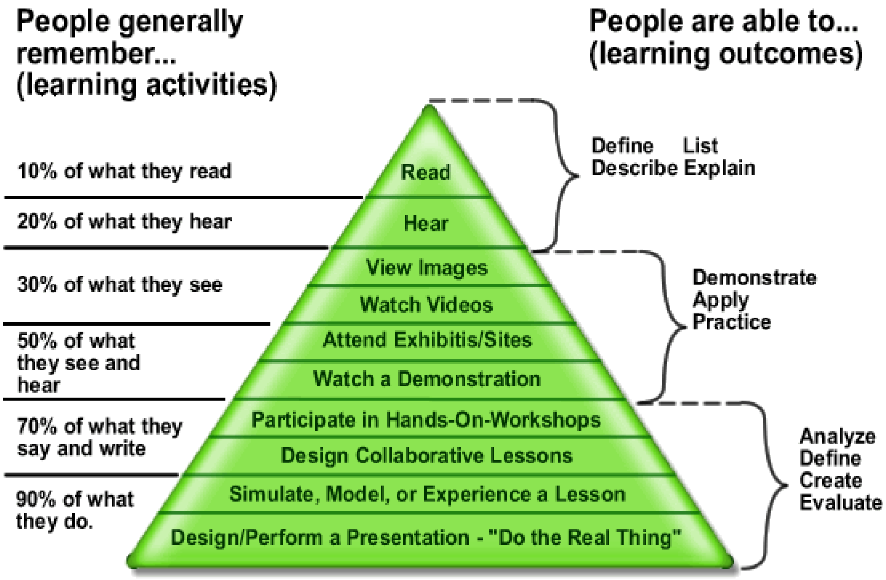

Figure 3.9: Cone of Experience after Edgar Dale, Graphic from Jeffrey Anderson, License under CC BY SA 3.0

framework supports interaction in the classroom combined with MOCCA as a teaching concept. This virtual one-to-one teaching approach introduced will be able to cover the areas *Read and Hear*, *Watch Images and Videos* as well as *Watch a Demonstration / Explanation*.

3.3.3 Teaching Method Categorisation

In Section 3.2 we introduced nine different learning methods, which we categorise by two different dimensions in this subsection as seen in Figure 3.10. The x-axis denotes if the specified learning method is either teacher-centred or student-centred[1]. The y-axis denotes if the learning method is high-tech oriented or low-tech oriented. All teaching-concepts covered which are based on a teacher-centred approach are highlighted in red, whereas all covered teaching-concepts which are student-centred are highlighted in green. AMATI and MOCCA can be categorised in the student-centred and high-tech area of this categorisation.

[1] https://teach.com/what/teachers-know/teaching-methods/#studentcentered

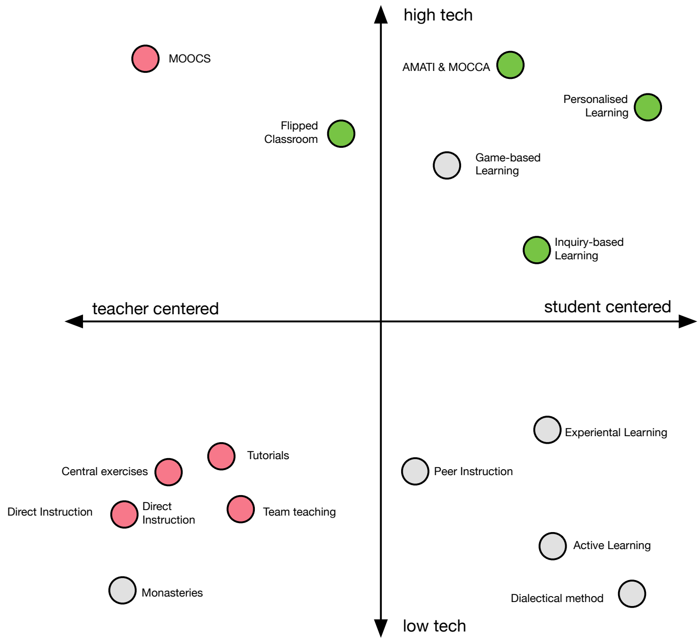

Figure 3.10: Categorization of learning methods into student or teacher centered design and low or high technology requirements based on Teach.com

3.4 The MOCCA Model

This section is based on the foundations of Section 3.1 and findings of Section 3.2, it describes the MOCCA teaching model and its most important abstractions. First we introduce general terminology in particular the definition of Teaching, Knowledge and Communication. Based on those terms we will construct this teaching model from bottom up by introducing sub-models with their according definitions. A birds eye overview of the complete teaching model can be found in Appendix 2.

3.4.1 Teaching / Learning

According to Ronald T. Hyman, teaching is not any kind of interaction, between teachers and students. Some content needs to be taught and learned, some knowledge, values, or skills needs to be passed from one individual to another, preferably all thee [Hym74].

> “ Teaching goes beyond conditioning or drilling by rote repetition. Neither drilling nor conditioning really aims at understanding and appreciation.
>
> *Francis J. Buckley* ”

According to Israel Scheffler, teaching may be characterised as an activity aimed at the achievement of learning and practices in such manner as to respect the students intellectual integrity and capacity for independent judgement [Hym74]. According to Buckley [Buc99] teaching is process and learning is its goal. He states the following:

> “ Teaching is a process. Learning its goal. When teaching is most successful, both students and teachers learn, if little or no learning takes place, the teaching has been unsuccessful.
>
> *Francis J. Buckley* ”

In this thesis, both students and teachers are *knowledge carriers* and *knowledge receivers* as seen in Figure 3.11, this follows Francis J.Buckleys definition.

3.4.2 Knowledge and Knowledge Item

According to the Oxford dictionary[2], knowledge is defined as

> “ facts, information, and skills acquired through experience or education; the theoretical or practical understanding of a subject. ”

In this dissertation, we reuse the existing definition of knowledge, in addition we define the term *knowledge item* as a discrete set of attributes, which bundled together are used for transferring knowledge from one person to another. A *knowledge item* consists of a *question* phrased by a *knowledge receiver*, its related teaching *context* linked and an *answer* provided by a *knowledge carrier* as seen in Figure 3.11.

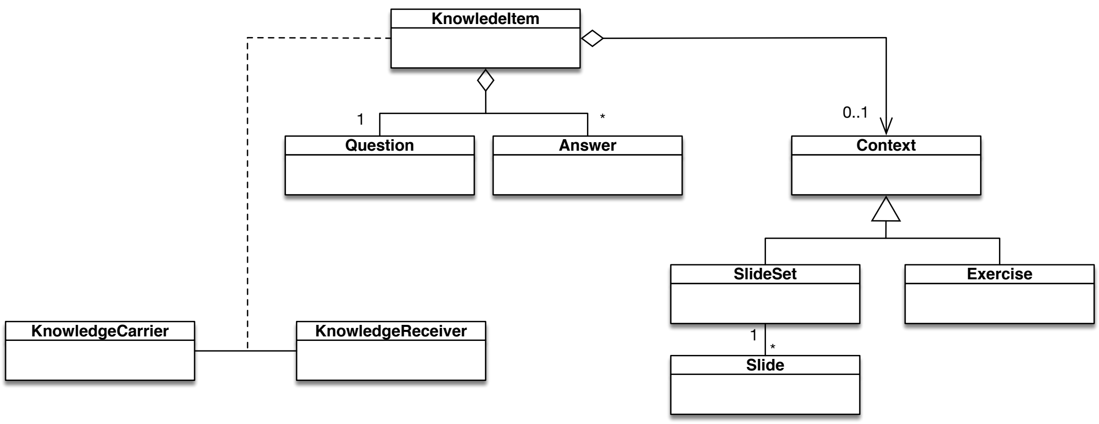

Figure 3.11: KnowledgeItem definition (UML class diagram)

[2] https://www.lexico.com/en/definition/knowledge

3.4.3 Communication

According to the Oxford dictionary[3], communication is defined as

> “ The imparting or exchanging of information by speaking, writing, or using some other medium ”

We refine this definition to reflect new means of communication by using remote and digital communication as follows:

> “ The exchange of teaching relevant information by speaking, writing, and using new means of digital exchange in form of smart devices. ”

3.4.4 Course

A course is defined by the Cambridge dictionary[4] as

> “ a set of classes or a plan of study on a particular subject, usually leading to an exam or qualification. ”

We would like to keep the given definition, *classes* in our scenario are interchangeable with the the definition of *lectures*. In addition to the definition of a course itself, its parts will be described in the upcoming paragraphs which contain the following elements; multiple teachers, rooms, different types of communication, assessments and lectures based on a single syllabus as seen in Figure 3.12.

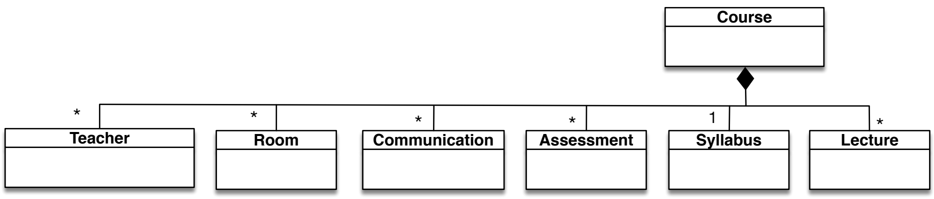

Figure 3.12: Course component composition (UML class diagram)

3.4.5 Teacher

A teacher is defined as follows according to the Cambridge dictionary[5]

> “ a teacher of a college or university subject, who usually teaches a limited number of classes. ”

[3] https://www.lexico.com/en/definition/communication
[4] https://dictionary.cambridge.org/de/worterbuch/englisch/course
[5] https://dictionary.cambridge.org/de/worterbuch/englisch/teacher

In addition to this definition, we consider that a teacher is either a student or an instructor as seen in Figure 3.13. As MOCCA allows for peer instruction as described in Subsection 3.2.8 we encourage discussion, and therefore students can be teachers on their own by providing meaningful information and *knowledge items* as seen in Subsection 3.4.2 to their fellow students.

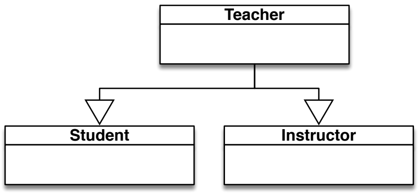

Figure 3.13: Teacher definition (UML class diagram)

3.4.6 Assessment

Assessment is defined by the Cambridge dictionary[6] as

> “ the act of judging or deciding the amount, value, quality, or importance of something, or the judgment or decision that is made. ”

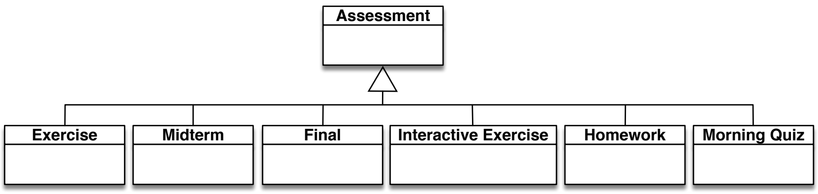

Figure 3.14: Assessment definition (UML class diagram)

Assessment in university environments is present in different forms starting from regular exercises over midterm and final exams to interactive exercises. For the introduction of AMATI and MOCCA we propose a new type of assessment called a morning quiz. We define a morning quiz as follows:

> “ A morning quiz is an assessment method executed at the beginning of each lecture. It contains between five to ten basic questions based on content delivered during the previous lecture held. ”

Basic questions should be chosen in a way that teachers are able to reflect on the state of knowledge of the student population in regards to heterogeneity and pre-existing knowledge. This allows to create a baseline for teaching content in upcoming lectures.

[6] https://dictionary.cambridge.org/de/worterbuch/englisch/assessment

3.4.7 Lecture Component

A *lecture component* can be seen as a discrete component used for knowledge transfer. Typically, it is based on a specific *content* which is taught in class, in addition to readings or websites. Lecture components can be chained together using a composite design pattern [Gam95] approach to create complex structures of knowledge for example questions, their related answers including their related content and readings.

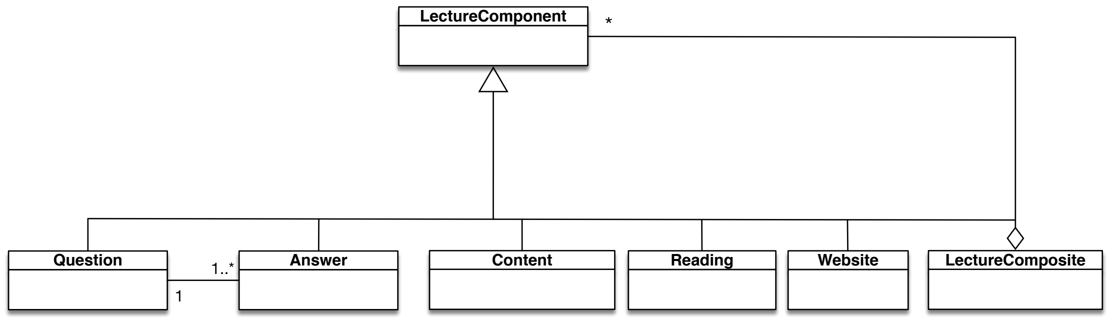

Figure 3.15: Lecture Component definition (UML class diagram)

3.4.8 Content and Content Views

We define *content* or *lecture content* as a composite with three important aspects as seen in Figure 3.16. First, *lecture content* has to be defined by having a *topic* as well as an *objective*. This is based on constructive alignment after John Biggs who states that a teaching topic should always be mapped to its according objectives in coordination with a an assessment method which fits the regarding topic [Big96].

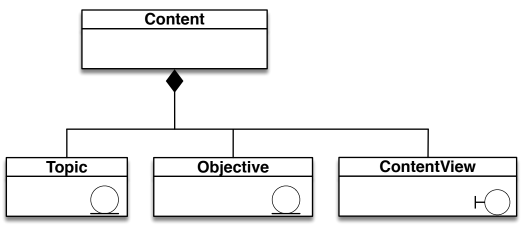

Figure 3.16: Content definition (UML class diagram)

Second, *lecture content* also contains what we define as *content view*. A *content view* can be either a analog content provider in the form of a *manuscript* or a *wallboard* in the form of white or blackboard or a digital content provider in the form of student polling using a *quiz* or providing teaching information using *slide sets* or other forms of digial lecture material as seen in Figure 3.17.

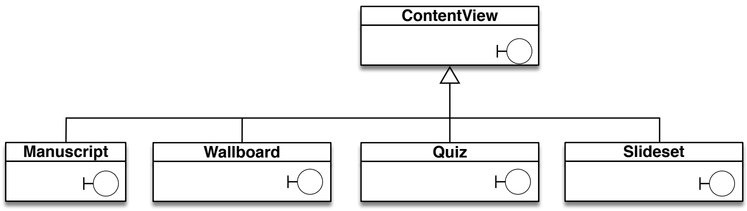

Figure 3.17: ContentView definition (UML class diagram)

Chapter 4

MOCCA - A context based dialectic teaching Methodology

> The important thing is not to stop questioning. Curiosity has its own reason for existence. One cannot help but be in awe when he contemplates the mysteries of eternity, of life, of the marvelous structure of reality. It is enough if one tries merely to comprehend a little of this mystery each day.
>
> Albert Einstein

Given the different teaching methodologies stated in the previous chapter, the question arrises why certain teaching concepts do not work as good as intended. Bernard Bass described in [Bas79] an experiment he conducted analysing the correlation between the size of meeting rooms and their according number of participants and their respective participation rate.

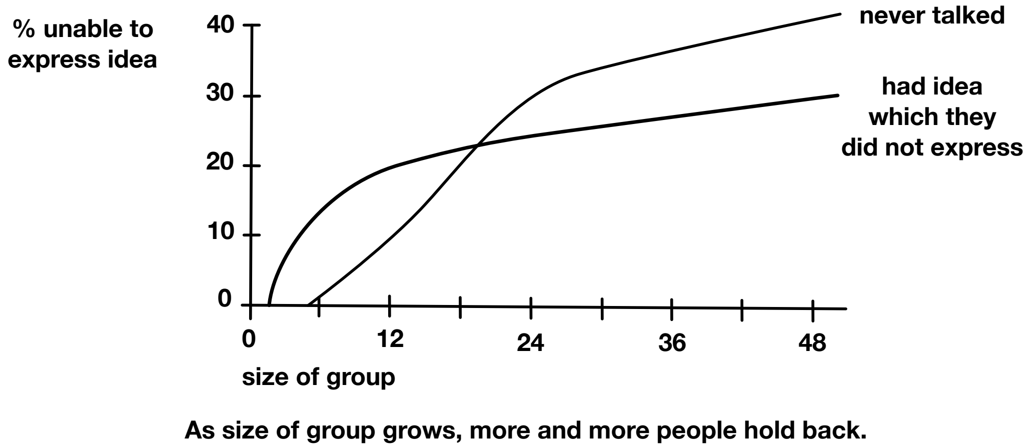

Figure 4.1: Participation depending on group size

As Bernard Bass observed, the more participants are in a room, the more people hold back to express ideas and interact. His observation was based on a group size

for 48 persons participating in a single room. Bernard Bass states that the best way solving this problem is to provide smaller distributed meeting rooms of a maximum of fifteen persons. However, this principle is often not applicable for large scale university lectures. Neither the envisioned room constraints according to Bass can be full-filled nor the pure amount of instructors for organization and lecture execution can be provided. If applied to a classroom where up to 1625 participants are distributed across several large lecture halls being connected via live-stream can be considered as a very strong example of this principle. In addition, this setup only provides a single instructor to actively participate in one of the available rooms. This shows that the provision of adequate communication tools are needed to optimize this situation in regards to information exchange from students to instructors. As seen in Section 3.2.3 the TUM also tackles this problem by introducing up to 60 tutorial groups for a single subject like EIST in the summer semester 2018 which are held by student tutors to reduce the number of students per room to about 25 persons. However, this concept only applies for the additional tutor sessions offered in addition to the typical centralized direct instruction lecture.
Section 4.1 introduces MOCCA a Massive On Campus Course Architecture, which addresses the stated problem by allowing in-class discussions and using a dialectic approach for communication. It describes the different components of MOCCA with respect to their underlying teaching methodologies leading to the requirements identified based on Section 6.2.

4.1 A context based virtual one-to-one teaching approach

One major component of MOCCA is the application of virtual one-to-one teaching. We define virtual one-to-one with the following pre- and post conditions:

Pre-conditions

A.
Student to instructor ratios up to 1625 students for one single instructor.

B.
Multiple lecture halls used for a single course by applying live-streams as room constraints do not allow to fit all students in a single room.

C.
Active students that contribute to the class by asking questions delay the lecture content delivered by the instructor.

Post-conditions

A.

A virtual student to instructor ratio of 1 student for 1 instructor.

B.

Time-dependent and *location-independent* teaching.

C.

The lecture flow is not delayed due to the *active teaching* component of answering questions and encouraging discussion.

Looking back to the beginnings of education, a one-to-one teaching ratio was a very personalized and student tailored experience in which room for discussion and argumentation helped to *"absorb with the pleasures in the soul"*[Pla0 b] and encouraged students to discuss and participate by using *active and experiential* teaching approaches. The goal of this dissertation is, despite an increase of 89% in first year university students in the last 15 years in Germany, to create a personal teaching experience allowing students to actively participate in the classroom similar to peripatetic schools as founded by Aristotle[Uni16]. To address this problem we follow the following three steps:

1. Examination of existing learning methods and teaching concepts

We examine existing teaching concepts which try to tackle some of the existing problems in MOCCs. Existing learning methods have been described in Section 3.2 with reference to their implemented teaching models in Section 3.4.

2. Examination of existing Tool Support

We examine existing support for interactive teaching concepts using new means of technology. How can we incorporate tools which are broadly available today to allow not just instructors to interact but also students to participate? Many of the existing tools described in Section 5 offer interaction possibilities for teachers to poll audiences but not in the direction from students to ask questions specific to lecture material to their teachers. None of the existing tool support offer the retrieval of the existing teaching context, nor are questions and answers stored in a way for easy access and reuse throughout a semester.

3. Adding new tool support and refining the existing teaching Concept
We iterate the existing teaching concept after incorporating new tools as traditional barriers for interaction may shift, leading to newly introduced communication overhead.

Before we introduce the different components of MOCCA, we address existing teaching concepts and their teaching ideas as follows:

The Theory of Recollection

In this dissertation we will address the existing means for questioning given by a raise-of-hand approach in large scale classrooms by introducing new digital ways of interaction in order to allow the establishment of a culture of inquiry by lowering interaction barriers and allowing a dialectic approach.

Blank Slate Theory

We are aware of the fact that student groups will have a heterogeneous knowledge. This is addressed by introducing different means of knowledge transfer in order to include as many participating students as possible. This is done by introducing morning quizzes as a self-check mechanism as well as offering a peer answering system in which strong students can assist weaker students to digest new lecture material.

Cognitivism

In this dissertation we emphasize on the idea of working on in-class exercises and home-works in order to address individual learning styles. In addition we provide further reference materials like books, websites and tutorials in addition to lecture material presented to encourage students to find their best suitable way to digest different lecture topics.

Constructivism

In this dissertation we will use techniques of constructivism in example of a provided morning quiz to assess student levels. This information can be used to tailor teaching material to a basic level as a common ground for solving more complex problems by the student population.

Active Learning

In this dissertation we engage students by introducing and encouraging discussions in the classroom by introducing two different means to handle this requirement. First, a teacher centred quiz is introduced, which allows to engage students to participate and poll their existing knowledge. Second, students are given the possibility to phrase questions anonymously regarding lecture content provided without suspending the lecture.

Team Teaching

In this dissertation we acknowledge the idea of multiple instructors to highlight important aspects, however consider parallelizing the influence of multiple teachers as a key factor for scalability and a personalized teaching approach.

Dialectical Method

We incorporate new means of communication namely AMATI to increase critical thinking during lectures in order to encourage knowledge transfer.

4.2 The Morning Quiz

A morning quiz during the first 10 minutes of each class allows students to demonstrate existing knowledge and prepare for new content. In addition, a morning quiz provides means for self-assessment for students and gives additional feedback to the instructors to potentially customize teaching content. A master thesis conducted by Johannes Flemke showed the technological feasibility to implement a system which uses morning quizzes and according tags to semi-automatically update existing teaching material in the form of slide-sets based on quiz scores achieved by the student population. [Fle15]

4.3 The Dialog

Based on the principles of constructivism to actively involve students during the lecture and provide basic information to deepen understanding a dialog between instructors and students needs to be established. According to Scott Freeman, active learning by incorporating students into actively participating during the course can increase student performance [Fre+14]. This leads to our hypothesis *HP2* that the creation of new digital means in form of a dialog will possibly impact students examination results in a positive way as seen in Subsection 1.2. This dialog introduced should be created in a asynchronous way that the lecture is not stalled, however students get the experience of a dialectic exchange with their teachers. To support this concept we have introduced a moderator role, which provides answers to students in a dialectic way which is also traceable and reusable. This allows knowledge gained during this dialog to be shared among other students of the class as well as storing it for further analysis and provisioning in upcoming semesters.

4.4 The Live Feed

The *Live Feed* supports students with additional teaching content based on complete *knowledge item* sets including the provided context and moderated answers. This additional input stream needs to be able to allow customization on student needs. For example, to reduce distraction, students can filter *knowledge items* with respect to the teaching material presented by the instructor. Organizational questions and questions related to homework should not interrupt the teaching flow as this information does not hold any immediate benefit from releasing those information as additional information during lecture hours.

4.5 The Review Breaks

During review breaks, students receive the opportunity to refresh and refine what has been taught. In addition, this time can be used to synchronize multiple moderators and the instructor in regards of number of questions asked to certain teaching topics as well as teaching material which is difficult to understand. This gives the opportunity to tailor existing teaching material on the fly or review and repeat important aspects of lecture content delivered after the *review break*. This may allow a higher learning curve for the participating student corpus.

4.6 The Knowledge Base

The generation of knowledge by using a dialog based lecture design in a digital form offers the opportunity to store and reuse this existing knowledge. A knowledge base can be created by using all *knowledge items* available. In addition, student feedbacks on lecture material can be collected and presented to instructors. Creating weekly Portable Document Format (PDF) reports which provide summaries and mindmaps of the questions asked during class is a possibility to adapt the teaching concept to a flipped classroom approach in which students can rework and link the provided material with the existing lecture material.

4.7 The Exercise Support

Similar to tutorials as mentioned in Subsection 3.2.3, students should have the opportunity to enhance their programming skills by working on in-class exercises. This can be done by supporting the class with in-class tutors, which need to be scaled accordingly to the student corpus size. Another option is an automated assessment approach as described by Stephan Krusche using *Artemis* which provides means to reduce workload for the instructors so they are still able to execute exercises during class hours [KS18].

4.8 Scenarios

This section first describes typical teaching scenarios based on existing teaching concepts and their according tool support at the Technical University of Munich (TUM). Second, visionary scenarios are formed which highlight the key aspects on the application of the AMATI framework and MOCCA teaching methodology as a unified teaching approach.

4.8.1 Scenario #1 - Direct Instruction

Using direct instruction, there is a single instructor and many students. The teaching concept is based on knowledge transfer by either using the chalkboard or a projector presenting teaching material. The following paragraph describes a typical scenario based on the direct instruction schema:
John, a computer science student at TUM, is enrolled in the EIST course in the summer semester 2016. He enters the classroom and can barely find a seat as the overall student enrollment is larger than 1000 students and the lecture hall seats 800 students. Bernd, the instructor of the course, uses a powerpoint presentation to guide the students through the lecture material in this single 3 hour lecture slot. After a while, John does not understand a concept which has been described on a lecture slide on the projector. He raises his hand and waits for his request to be answered by Bernd, who in the meantime has proceeded to the next slide in his slide deck. After Johns request has been granted, John asks his question. Bernd the instructor flips back to the previous slide which contains the context for the answer. John still does not quite understand. After reformulating his question, Bernd comes with another explanation that satisfies John. Mary also tries to follow this dialog between John and Bernd, but does not fully understand the conversation between them. The lecture continues until the 10 minute coffee break for students to refresh themselves and talk to each other. After the coffee break the lecture continues until Mary raises her hand to ask a question which is answered by Bernd. This dialog continues with other students until the end of the lecture.
The scenario described can be abstracted to a typical workflow diagram highlighting the following identified components. The **ContentProviderItem** is a representation of either the Blackboard or the Projector highlighting the teaching material. A **lecture interrupt** always occurs when a student phrases a question by using his raise of hand methods to inquire for a break of content delivery. Based on the Decision of the lecture interrupt either a **discussion** is started to solve the question or the question is dismissed due to the fact that this questions has already been answered by the instructor before.

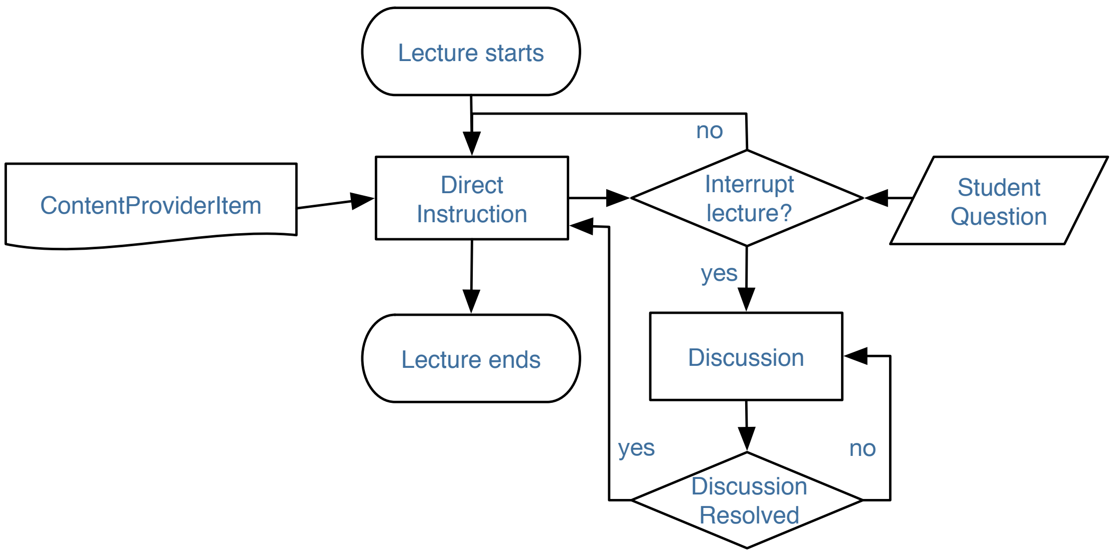

Figure 4.2: Direct instruction Scenario (Flowchart diagram)

4.8.2 Scenario #2 - Student Tutorial

When using student tutorials there is a single instructor who works with a small part of the full student corpus usually in addition to a typical direct instruction lecture as mentioned above. The idea of this approach is to reduce the instructor to student ratio and have a more individual supervision on specific exercises which have been selected to enhance student understanding. The following paragraph describes a typical scenario based on the student tutoring schema:

John, a computer science student at TUM, is enrolled in the EIST course in the summer semester 2016. In addition to his lectures he participates in a weekly tutorial with given exercises. He enters the tutorial room and takes a seat. As seats are accounted for the number of students it is not a problem for him to find an adequate seat. Roland his tutor introduces the first exercise of the day and highlights the importance of certain aspects. After the introduction John starts to work on his own to solve the given exercise. After a while, John does not understand a concept which has been described and therefore looks up more information on the lecture slides. After not being able to find the necessary information in the full slide deck he raises his hand and waits for his request to be answered by Roland. Roland collaborates with John and starts over explaining him one-to-one how to solve the given exercise based on Johns needs. In the meantime Mary, another student raises her hand and needs some help for the exact same exercise. After Roland finishes the explanation with John, he walks over to Mary and starts helping her on a different problem with the same exercise. After a certain time Roland presents a full solution to the first exercise and

introduces the second exercise of the day. This dialog continues with other students over many more exercises until the end of the tutorial.
The scenario described can be abstracted to a typical workflow diagram highlighting the following components. The **ContentProviderItem** is a representation of an exercise which has been created for the purpose of teaching certain curriculum concepts in more detail and deepen a students understanding. During **Exercise conduction** students work on their own on the given exercise material. If a **Student Question** is phrased a **1-to-1 Discussion** is started between the tutor and the student. However the Tutor is not able to start additional discussions at the same time until the ongoing discussion is resolved. During the **Exercise solution presentation** the tutor presents a sample solution which can be used for reference and clarification.

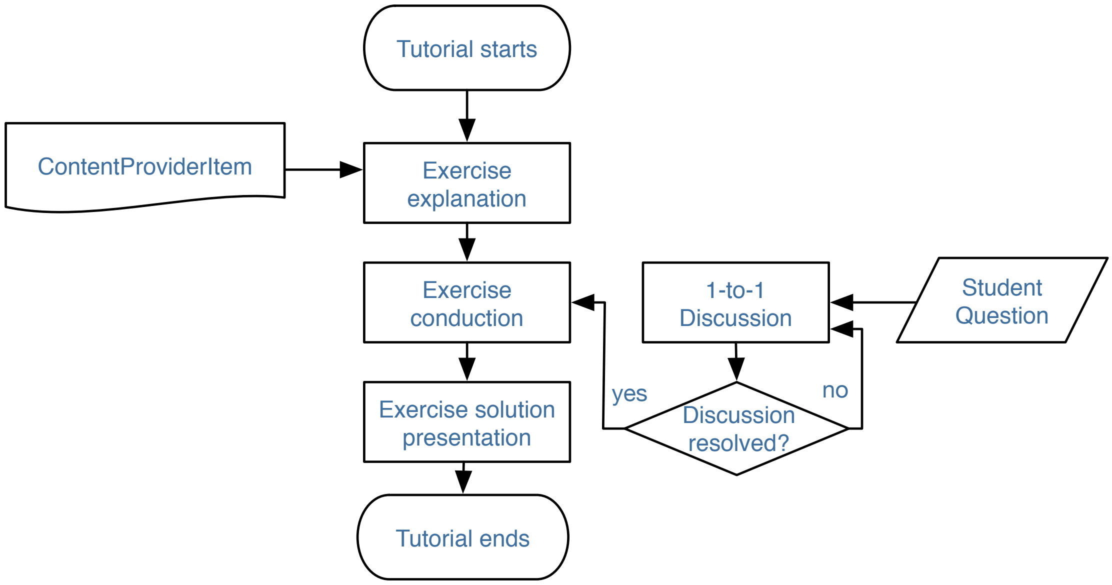

Figure 4.3: Student Tutorial Scenario (Flowchart diagram)

4.8.3 Scenario #3 - Centralised Exercise

In this Scenario, there is a single instructor who works with the whole student corpus. The centralised exercise mimics the setup of a traditional direct instruction setup described in Scenario #1 - Direct Instruction. The major difference is the content presented does not introduce new lecture material, but the existing teaching material is used to formulate exercises and formally present exercise and their according sample solution to the whole student corpus.
Mike, a computer science student at TUM, is enrolled in the EIST course in the summer semester 2016. In addition to his lectures he participates in a weekly centralised exercise

with presented solutions. Jan his instructor starts presenting the exercise task at hand. Based on the exercise he presents a common approach on how to tackle the underlying problem of this specific presented exercise. Mike does not understand the approach of solving the given exercise. He raises his hand and waits for his request to be answered by Jan. After granting the request, Mike asks his question. Jan the instructor tries a different explanation. Mike still does not quite understand. After reformulating his question, Jan comes with another explanation that satisfies Mike. Mary also tries to follow this dialog between Mike and Jan, but does not fully understand the conversation between them.
The scenario described can be abstracted to a typical workflow diagram highlighting the following components. ContentProviderItem, ExerciseConduction, Discussion, LectureInterrupt, StudentQuestion.

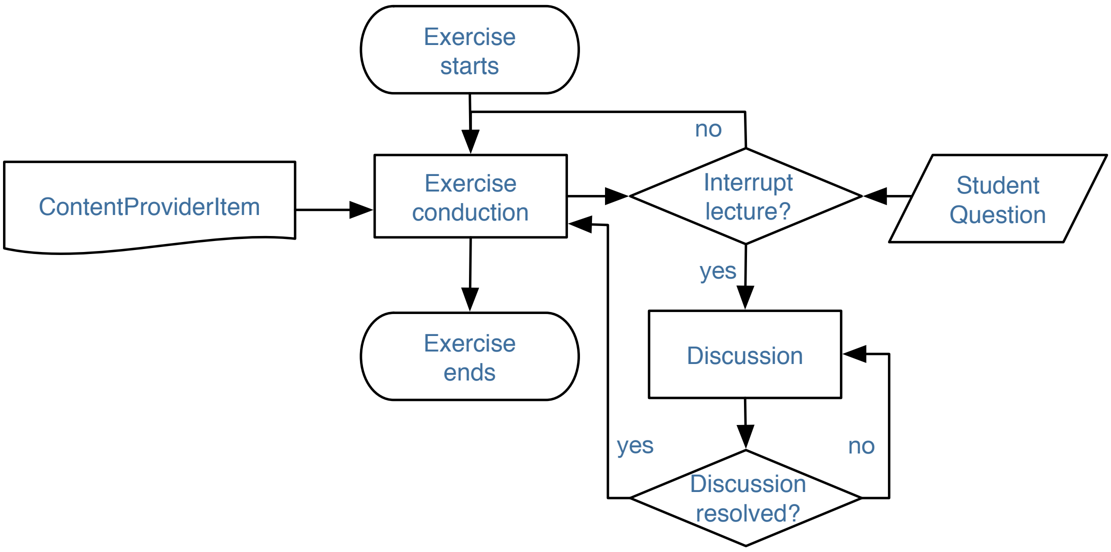

Figure 4.4: Centralized Exercise Scenario (Flowchart diagram)

4.8.4 Scenario #4 - Flipped Classroom

This scenario describes a different teaching approach compared to the typical teaching scenarios described before. While typical scenarios focus on knowledge transfer in form of exchanging teaching material during class hours, the flipped classroom concept aims on creating a very productive environment for asking and solving questions during class hours and have students prepare the lecture material out of the lecture.
John, a computer science student at TUM is enrolled in the EIST course in the summer semester 2016. During the first lecture of the course, Bernd the instructor introduces new important lecture material and readings to be done by the students at home until

the next lecture. In the next lecture, John has prepared the given material however was not able to understand all the given readings at its fullest. So John prepared some questions which he asks to Bernd. Bernd starts the lecture by again introducing new material and readings for preparation. After those announcements, Bernd uses the remaining lecture time to answer as many student questions as possible.
The scenario described can be abstracted to a typical workflow diagram highlighting the following components. ContentProviderItem, MaterialIntroduction, MaterialPreparation, Q&A for Material and StudentQuestion.

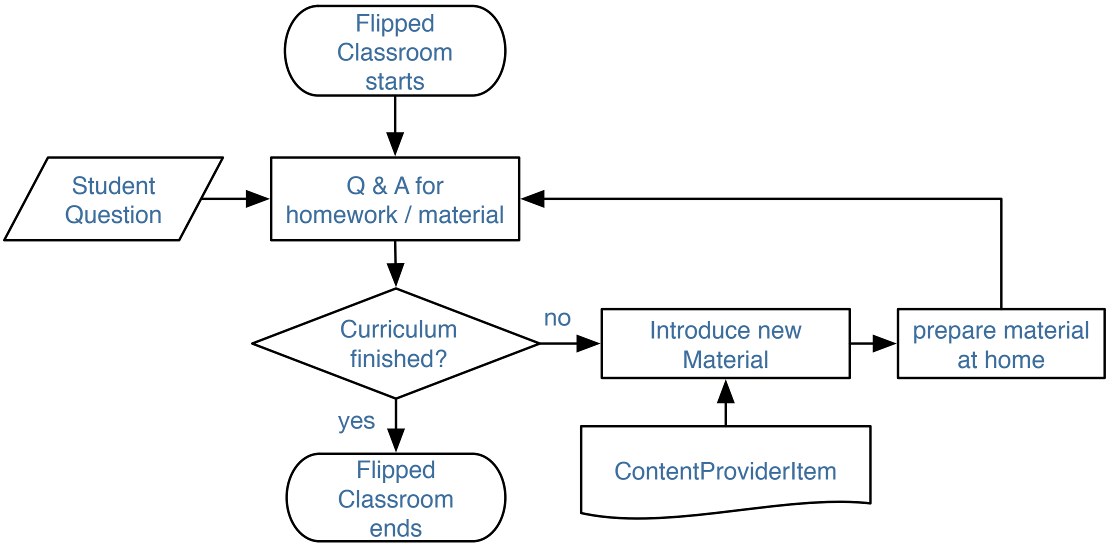

Figure 4.5: Flipped Classroom Scenario (Flowchart diagram)

4.8.5 Scenario #5 - Peer Instruction

This scenario describes a typical peer instruction setup. First, teaching material is briefly explained by the instructor. Then a short quiz is taking place and depending on the result percentage of correct answers different actions are executed. Either the instructor refines his explanations, a peer discussion is started or the quiz results are briefly elaborated.
John, a computer science student at TUM is enrolled in the course Algorithms and Data structures in the summer semester 2016. During the first lecture of the course, Bernd the instructor briefly introduces new lecture content. Based on this new lecture content, Bernd starts a quiz to assess the existing knowledge based on the topics introduced.
John as well as all other students in the classroom participate in the quiz. Since the overall percentage of correct answers is about 60%, Bernd the instructor starts a

peer discussion round in which John collaborates together with Andrea and Sarah, to understand why certain answers given have been right or wrong. After the peer discussion round, Bernd gives a final feedback in a form of a brief explanation about the topics presented. After that Bernd uses the remaining lecture time to repeat this process and starts over with more new content.

The scenario described can be abstracted to a typical workflow diagram highlighting the following components. ContentProviderItem, MaterialIntroduction, BriefDirectInstruction, Quiz, PeerDiscussion, BriefExplanation and DirectInstruction.

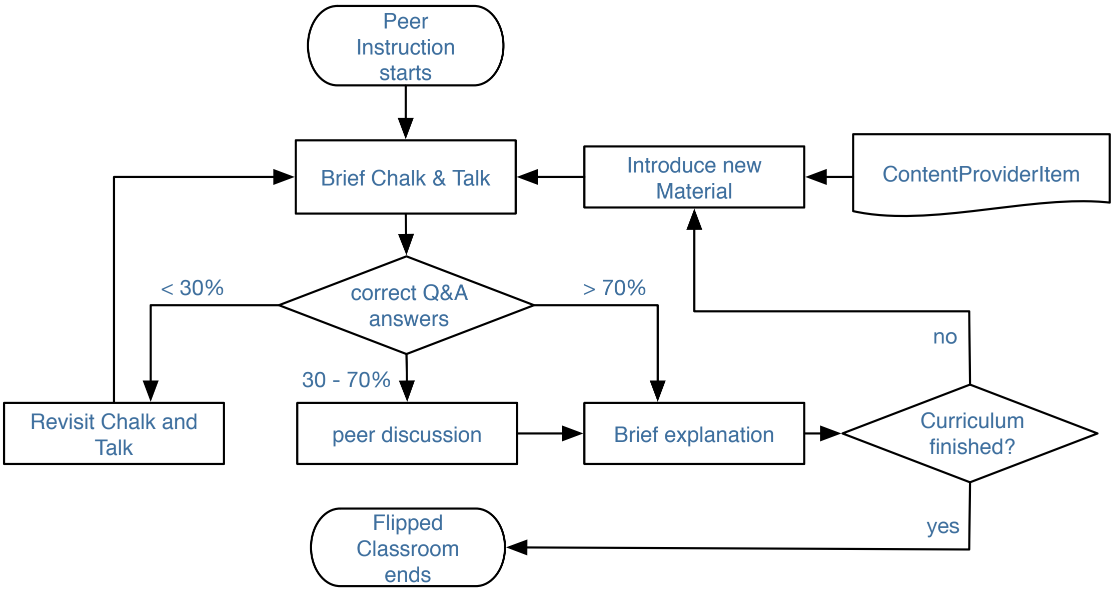

Figure 4.6: Peer Instruction Scenario (Flowchart diagram)

4.8.6 Visionary Scenario #1 - AMATI 2016

This scenario describes a typical scenario applying AMATI during the EIST lecture in the summer semester 2016. First, the instructor starts the so called morning quiz using AMATI. This morning quiz elaborates on existing student knowledge. Based on the Quiz results the lecture material will be adapted semi-automatically to remove unnecessary content and add additional lecture content where applicable. After the morning quiz, the lecture starts with the tailored lecture material in which students can use AMATI to phrase questions related to certain teaching content using so called hashtags (#). Whenever a student asks a question a moderator will be notified and can provide answers to the students using AMATI. During review-breaks the moderator synchronizes with the instructor and informs him about the most relevant questions

phrased. The lecture continues until all lecture material is presented or the lecture time ends. This scenario can be described as follows:
John, a computer science student at TUM is enrolled int he course Einführung in die Softwaretechnik in the summer semester 2016. At lecture start, Bernd the instructor asks students to participate in a morning quiz using AMATI. After the results have been evaluated the lecture content is customized semi-automatically based on the quiz results. Bernd continues to present the new lecture material. John does not fully understand a certain aspect on a Slide about UML modeling. He phrases the following question using the hashtag #UML: ”What does the empty arrowhead mean in a UML class diagram”. Jan the moderator receives the question and answers as follows: ”In UML the empty arrowhead stands for a special type of connection between two classes namely inheritance. Inheritance denotes a parent-child relationship.” After the answer has been provided John is able to lookup the given answer in AMATI and continues to follow the lecture content. Jan the moderator can now focus on new incoming questions while Bernd is continuing to present the new lecture material without any interruption.

4.8.7 Visionary Scenario #2 - AMATI 2017

This visionary scenario describes the adaptation from AMATI 16 to AMATI 17, as the hashtag-approach has been removed in favour of receiving a specific teaching context from the teaching material presented from the instructor. In addition to teaching context, *knowledge item* sets are presented on a second projector to allow students to follow on specific important answers of their concern, while a chatroom provides answers as personal messages for their specific questions to reduce distractions.
John, a computer science student at TUM is enrolled in the course Einführung in die Softwaretechnik in the summer semester 2017. At lecture start, Bernd the instructor asks the students to participate in a morning quiz using AMATI. After the results have been evaluated the lecture content is customized semi-automatically based on the quiz results. Bernd continues to present the new lecture material. John does not fully understand a certain aspect on the slide presented about UML modeling. He phrases the following question: ”What does this empty arrowhead mean?”. AMATI pulls the active lecture slide as a reference and shows the question including the teaching context to Jan the moderator and all other students participating in AMATI. Maria another student participating in the lecture provides the following answer to John: ”AFAIK the arrowhead denotes inheritance”. Jan the moderator marks this answer as a correct answer. The verification process of AMATI publishes the given Question its teaching context and its according answer on a second projector available in the classroom to allow all participating students to detect this potentially interesting

question. The lecture continues with multiple questions from different students and the moderator Jan answers as many of them as possible. After the lecture has ended, Jan the moderator and Bernd the instructor review all the questions and answers provided in AMATI using the AMATI dashboard. Jan realises that there have been many questions asked to some specific slides and recommends Bernd to adapt certain lecture material to ease understanding. Finally, Jan creates an PDF export containing all *knowledge item* sets of this session and uploads the document on the lecture content management platform Moodle so it can be provided to all students.

4.8.8 Visionary Scenario #3 - AMATI 2018

This visionary scenario describes the adaptation from AMATI 17 to AMATI 18, in which retrieving the lecture context via an *PresenterClient* has been replaced by offering students the possibility to state questions directly to specific lecture slides offering a new interface of the AMATI framework.
John, a computer science student at TUM is enrolled in the course Einführung in die Informatik II in the summer semester 2018. At lecture start, Jan the instructor asks the students to participate in a morning quiz using AMATI. After the results have been evaluated the lecture content is customized semi-automatically based on the quiz results. Jan continues to present the new lecture material. John does not fully understand a certain aspect on the slide presented about UML modeling. He opens up the AMATI website selects the session and the according slide he has questions about. He phrases the following question: "What does this empty arrowhead mean?". AMATI notifies Jonas as a course moderator and that there is a new question which needs his attention. Jonas the moderator provides an answer to the question provided. The verification process of AMATI publishes the given Question its teaching context and its according answer on a second projector available in the classroom to allow all participating students to detect this potentially interesting question. John marks this slide as understood after receiving the answer via AMATI. During the session, John keeps track on all the lecture material he immediately understood and is taking notes via AMATI using the notes feature on all slides where he needs to recap after the session. After the session is over, John is able to generate a report of all presented lecture slides in addition to his comments and all question and answer sets which have been provided by all students.

4.9 The MOCCA Workflow and Activities

Based on the visionary scenarios in the previous section and the definition of the different MOCCA activities in this chapter we formulate the MOCCA workflow as seen in Figure 4.7. The MOCCA workflow starts with the conduction of a morning quiz by students. The results of the *morning quiz* are used to refine and tailor lecture material. In order to allow the student dialog to be enhanced with context, the *presenter client* needs to be stared by the instructor. Next, a direct instruction activity or a supervised exercise activity is started. Both activities are supported by the moderator in form of a question dialog and a live-feed which presents *knowledge item* sets to students. By introducing *review breaks*, instructors and moderators have the chance to synchronize about incoming student questions. When the lecture ends, the moderator provides students with all *knowledge item* sets generated during this lecture.
All student transitions are highlighted in red, whereas instructor transitions are highlighted in blue and moderator transitions are highlighted in green.

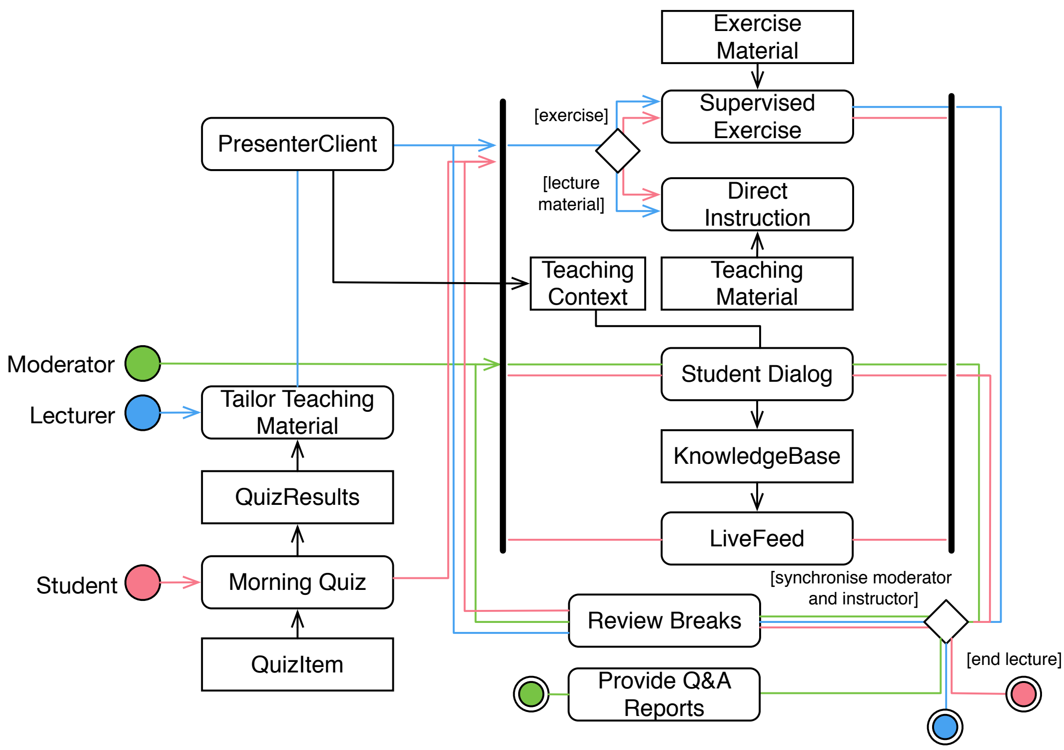

Figure 4.7: The MOCCA workflow (UML activity diagram)

Chapter 5

Software Engineering Education Tool Support

> For the human makers of things, the incompletenesses and inconsistencies of our ideas become clear only during implementation.
>
> Frederick P. Brooks

This dissertation is inspired by existing tools that are able to improve in class communication in different ways. AMATI incorporates proven concepts from software solutions stated below while extending the functionality to integrate new concepts described in Chapter 8. This section introduces each of the tools in more detail, highlighting *pros* and *cons* during their use in public universities and according to our personal experience.

5.1 OnlineTED

OnlineTED [Onl17] is a web based audience response system for higher education that uses the students own internet-enabled devices to participate in in-class quizzes. The main objective is the assessment of students knowledge during a lecture which serves as a starting point for a discussion. The quizzes are supposed to increase the students' attention and promote interaction even with large classes. Early results show that web based audience response system seem to perform better than traditional systems using clickers but are highly dependent on a available WIFI or mobile data connection[Med14]. While it can not be used as Q&A system for students, having the ability to probe students knowledge during class provides instructors with a powerful tool to adjust lectures on the fly to improve the learning outcome.

5.2 Tweedback

Tweedback [VGC13] is a system similar to OnlineTED to gather feedback during lectures. It consists of three independent feedback channels: pre-built quizzes to be asked by the teacher, anonymous questions from students on a chat wall, and a so called problem button to communicate concrete problematic situations such as "voice to quiet" or "please give an example". The results from these channels are shown to the instructor in a web interface and a summary of the lecture can be received via email after the lecture. The questions by students are asked anonymously and students can up-vote questions of interest as well as provide answers to them. When a question gets enough up-votes the instructor is notified and can decide to address the question. This approach has several problems. Questions that concern only a small number of students get very few up-votes and are never addressed. The inherit problem to this approach is that question and answer get split up into two different communication channels using a software platform for asking questions and spoken word for answers provided by instructors. This makes it difficult to persist the generated knowledge due to distribution of artifacts. Question, answer, and context are spread over different channels and technologies compared to a single *knowledge item* set. This system claims to indicate critical situations to the professor, but fails at addressing individual needs of students as all data collected is focused on a majority of students rather than the individual student. Furthermore, the idea of providing feedback to the instructor is a good approach but instructors need to divide their attention which can have a negative impact on the lecture quality. Another downside of Tweedback is that generated knowledge can not be made available for students after the lecture as there is no knowledge repository because the data collected is captured individually per lecture. This also prohibits complex data analysis for teaching staff without doing a large amount of additional work.

5.3 Slack

Slack is a chatroom application service with the intended use case to eliminated the need for emails in business environments completely[1]. Early 2017, *Slack* rolled out a feature called *Threads*. This feature allows users to reply to a message directly and have message and replies organized in a small sub-conversation. The motivation behind this feature was to group messages that talk about the same topic to avoid cluttering the channel with messages. Without threads, a *Slack* channel can quickly get very hard to follow because multiple sub-conversations overlap. The message that starts a

[1] https://www.slack.com

thread can be seen as a sort of context that all replies relate to. The implementation of this feature shows that the developers of *Slack* have realized how important context can be for a textual conversation. The AMATI framework will make use of this new feature by opening new threads for each question stated by students.

5.4 Moodle

One of the most well known Learning Management System (LMS) tools is *Moodle* which is provided as open source software. It is free to use for educational institutions. According to the Moodle website[2] more than 100.000 institutions are actively using Moodle in their teaching environments. This led to a large user base and community working on additional features. Out of the box, Moodle supports collaborative features like forums, assignments with peer-reviews as well as file and lecture material organisation. However Moodle can not neglect its history as it was originally designed and used as content management system for educational environments.

5.5 Feedbackfruits

The software *feedbackfruits* is actively developed by the TU Delft [3]. In its current development it allows the integration into moodle and other LMS platforms. *Feedbackfruits* is based on a similar concept as Slidoo [Sli19] in which students can be polled for questions and results can be evaluated for instructors during interactive presentations. While writing this dissertation, *feedbackfruits* introduced a beta version to allow the upload of presentation material onto its platform. In addition to interactive presentations, *Feedbackfruits* offers peer-review assignments, group member evaluations, assignment and skill reviews similar to moodle functionality or achievable with moodle plugins.

5.6 Pingo

Peer-Instruction for very large groups (PINGO) is a free to use question polling tool for audiences[4]. It allows the user to prepare moderator questions or ask ad-hoc questions. It requires internet enabled devices to participate. The moderator can present the results of polls either embedded in Microsoft PowerPoint presentations or via web-browser. As question-types, single-choice, multiple-choice and numeric questions can be created. *Pingo* does not allow student questions and it is focused on teacher polling.

[2] `https://moodle.org/`
[3] `https://feedbackfruits.com`
[4] `https://trypingo.com/de/`

Chapter 6

Requirements Elicitation for a unified Teaching Methodology

> According to UNESCO, in the next 30 years more people will receive formal education than in all of human history thus far
>
> Sir Ken Robinson

Based on different communication tools with educational support described in Section 5 as well as the analysis of existing teaching concepts in Section 3.2, this chapter highlights the key aspects identified as requirements for a new teaching framework solution namely AMATI and its applied teaching concept MOCCA.

While several studies from Joshua Angrist [AL97], Ronald Ehrenberg [Ehr+01] and Caroline Hoxby [Hox00] provide different results on the impact of high student numbers per class on student performance, statistics definitely show that student enrolment numbers are increasing year by year in the last decade. The federal statistics office [Ger17] in Germany published the following numbers in 2018: 230,670 students have been enrolled in Germany in the winter semester 1998/1999, whereas there have been 437,737 enrolled students in Germany in the winter semester 2017/2018. This evidently leads to larger class sizes and in many cases also to higher student to instructor ratios. Keeping the growth of student population as a considerable factor to adapt the communication process for MOCCs the identification of requirements for the software framework AMATI was an iterative approach. After providing an initial version of the AMATI framework during the EIST course in the summer semester 2016, in which different communication ideas have been tested (student questions, teacher polling), we realised that student involvement can not be easily changed by just introducing a new medium of interaction. The applied teaching concept in form of direct instruction needed to be adapted and the resulting changes are described in Section 6.2. Also new requirements for the AMATI framework emerged which are pointed out in the following subsections.

6.1 AMATI Requirements

Based on our findings during EIST course in the summer semester 2016, four important requirements for the AMATI framework have been found which will we elaborated in the following subsections. The first requirement covers the fact that AMATI has to be able to deal with a high frequency of student questions contrasted with a high student to lecture ratio up to 1400 students to 1 instructor. The second requirement should allow the instructor to phrase in-class questions to students to poll for existing knowledge. The third requirement should allow all student to teacher interactions to be in a time-dependent but location independent manner, as students should have the choice to participate in the main lecture hall, in additional lecture halls via live-stream or even from remote locations via internet live-stream. The fourth requirement is to lower the barriers of interaction considering physical, psychological and technological barriers to allow students to actively participate.

6.1.1 AMATI Requirement 1: Asynchronous in-class student questions

The situation of a single instructor and multiple classroom setup described can have a severe impact on knowledge transfer in traditional lectures since asking questions is usually done by the raise of hand method. In addition, the instructor is provided with the option to either accept the question while suspending the lecture or dismiss the question and proceed with content delivery. Halting the lecture however leads to lost lecture time which is considered to be the time that could be used to deliver new content to students but instead is used to elaborate on previous delivered content due to a question. The idle time for students not concerned with the question is the same as the lost lecture time but multiplied with the number of students not concerned with the question. The lost lecture time and student idle time can be modeled with mathematical formulas to show the influencing factors. The lost lecture time shall be called t_{lost} and the student idle time t_{idle}. Given the number of students n_s, numbers of questions asked n_q and average time to answer a question $\bar{t}_q$, the lost and idle times can be calculated with the following formulas.

$$t_{lost} = n_q \bar{t}_q \tag{6.1}$$

$$t_{idle} = (n_s - 1) n_q \bar{t}_q \tag{6.2}$$

Lets assume a class that allows all students to actively participate with a size of $n_s = 1000$ where only 5 percent of the in-class participants intend to ask a question $n_q = 50$ with an average answer time of one minute $\bar{t}_q = 1\ minute$. Following this assumption a instructor would have to spend up to $t_{lost} = 50\ minutes$ of in-class lecture time to address each question accordingly. This calculation does not even consider the idle times of students who know the answer to the given question already. This highlights the need of new means of interaction which also scale with high in-class student numbers.

6.1.2 AMATI Requirement 2: Synchronous in-class teacher questions

As one major goal is to achieve student interaction by participation, another important principle is the active polling of information from the students in the form of quiz questions allowing for a general representation of the knowledge state of the student population. This can be used for lecture content adaptation by removing certain lecture material from existing slide decks and therefore tailoring the student experience during or at beginning of lecture hours.

6.1.3 AMATI Requirement 3: Time-dependency and location-independency

The issue considering large student to lecture ratios described in Section 6.1.1 gets even worse considering the fact that due to high student numbers a single classroom is often not sufficient to accommodate all registered students. Students have the option to participate watching a live-stream of the lecture in a additional classrooms or use the possibility to stream lecture content from remote locations. Student participation however is impeded using separate rooms or video streaming since it is not supported by traditional means of interaction. Therefore, the third requirement for the AMATI framework is the incorporation of a communication channel which is time-dependent and location independent.

6.1.4 AMATI Requirement 4: Lowering barriers of Interaction

Due to the distinct nature of lecture participation described above, new barriers of interaction can occur which lead to additional technological and methodological challenges for the teaching staff. These barriers can be categorised in physical, psychological, and technological barriers which will be covered in the following subsections.

Physical Barriers

For students not participating in the main hall, it is impossible to ask question via the traditional method of raise of hand. In addition to the physical barrier from the students perspective the teacher also has a hard time interacting with students at remote locations or in different lecture halls. Therefore new means of interactions in both directions teacher-to-student and student-to-teacher have to be established.

Psychological Barriers

In addition to physical barriers there are psychological barriers, as students are intimidated by phrasing questions to a large audience especially when they do not know how to phrase their question properly according to Richard Anderson [And+03]. To address this requirement the AMATI framework needs to support (pseudo)-anonymity for students.

Technological Barriers

Physical and psychological barriers aside, new means of interaction between multiple lecture rooms have to be established. This also leads to the issue of context-awareness as students asking questions during class tend to refer to certain lecture material while phrasing their question. Given an example from the EIST course, a student phrased an in-class question in the following way:

> “ Is nickname not an attribute of any class? ”

The provided answer of the moderator was the following:

> “ You can add the attribute in the league class and have a hash map mapping the attribute nickname to the player class ”

The question was probably about a model of a software that handles some sort of leagues and players but this question-answer tuple does not carry any value for students not participating in the same lecture hall as the context or reference to the material discussed is missing. This relationship of questions and their context is especially important when there is a delay using a streaming service and students would like to phrase a question regarding lecture content which may have already has been passed in the main lecture hall.

6.1.5 AMATI Requirement 5: Lowering distraction and increasing in class communication

Approaches like flipped classroom or peer instruction after Eric Mazur[MH97] amongst others tend to delegate content delivery out of the classroom and therefore allow more time for discussion and exercises inside the classroom. A very similar separation can be seen in traditional teaching setups, where the separation is being done by splitting content delivery during class from exercises being held in tutorial sessions. This concept however is often realised by the use of student tutors, as instructors can not deal with the high amount of students on their own. This concept can be found at TUM in the form of tutorials and central exercises as seen in Section 3.4. Other approaches are combining exercises and content delivery inside the classroom [FB03] [BPS01] to deepen the understanding of students. The AMATI framework should allow in-class communication to deepen students understanding while keeping them focused during lecture hours and allowing content delivery.

6.1.6 AMATI Requirement 6: Reasonable instructor explanations

Online teaching approaches like MOOCs deal with this problem by offering automated corrections for exercises. However, automatic verification can be difficult to achieve if the existing solution space is large. For complex answers MOOCs often rely on peer reviews to achieve reasonable results as the automated correction and verification for complex questions especially in regards software engineering and other diciplines are non trivial. Furthermore, verification of correctness does not necessarily explain the reasoning behind a given correction. Often, peers are also not able to provide the additional knowledge needed for in-depth corrections and insights. Fred G. Martin describes his experiences to personal communication using small discussions each week in a MOOC as follows [Mar12]:

> “ Most of my students got a lot out of the fall Stanford course - and our weekly discussion sections made a difference. ”

Especially in software engineering and modeling, learning is not only about correcting student solutions but actually to guide students, to achieve knowledge transfer. Yet, the traditional concept of knowledge transfer by asking questions during class is getting less and less popular due to the fact students prefer anonymity in large classes [Cal07] and students often have a hard time to properly formulate their questions [And+03]. Therefore the AMATI framework to be introduced aims to enhance in-class questions by the inclusion of teaching context and also offering anonymity. This in return allows to generate a knowledge base which incorporates reasoning on lecture material and certain modeling decisions that has been made and also allows for further discussion about related material. In addition, the introduction of asynchronous threads for knowledge transfer allow to combine content delivery with discussions inside a single lecture.

6.2 MOCCA Requirements

The initial requirements for the AMATI framework defined, a shift in the educational method *direct instruction* is needed to apply AMATI accordingly. We propose a new teaching concept which we call Massive On Campus Course Architecture (MOCCA), which increases the personal communication between individual students and their instructor. The following sub-sections describe all the requirements identified to transform a traditional *direct instruction* teaching environment to a student-centred teaching environment.

6.2.1 MOCCA: Requirement 1: On Demand Delivery

Considering 1625 students in the EIST course at the TUM, instructors have a hard time to split their attention between different students in a short amount of time, for example if multiple questions are incoming. This is the case in particular when instructors have to deal with heterogeneous student groups and questions are only of concern for small groups of the audience. Yet, having smaller classes in general or having more time to devote to each student can be seen as beneficial [AL97][Mos95]. This leads back to requirement 6.1.1 as synchronous questions allow to deal with a certain amount of questions per session and also suspending the content delivery thread. While applying MOCCA it should be possible for the instructor to present teaching content without suspending for each individual student question. In addition students should have the opportunity to ask questions and receive direct answers for their questions that help them to increase knowledge transfer and deepen understanding towardas newly introduced material.

6.2.2 MOCCA: Requirement 2: Question Moderator

Traditional lectures are a teacher-centered approach, focusing on the dialogue between the instructor and the class as a synchronous process. To circumvent the issues described in Subsection 6.1.1 we propose a new moderator role to be included into the teaching setup. The moderator will take the synchronous load away from the instructor and will focus on answering questions from students using the provided AMATI framework. This reduces idle times for participating students waiting for new content and allows the instructor to keep delivering new lecture content. This approach is inspired by the methods used in a *team teaching* setup [Beg64], however the second teacher, in our case the moderator has to moderate all incoming questions, deliver answers to students and is also able to accept given answers from student peers to questions. The moderator should not replace or interfere with the instructor, yet provide new means for students to ask questions without suspending the lecture flow. A moderator can be any person which is qualified to answer student questions properly, by having the required knowledge of a certain subject. In our case study of EIST in the summer semester 2017 a single teaching assistant as well as a single tutor was used to provide answers to incoming questions. In the EIST case study in the summer semester 2018 multiple teaching assistants in addition to multiple tutors were used.

6.2.3 MOCCA: Requirement 3: Additional content projector

Traditional lectures usually use a single projector setup to transfer lecture content. We propose the use of an additional content projector. This second projector takes the role of automatically providing moderated *knowledge item* sets, the moment the a moderator provides a given answer. This allows students to receive knowledge generated from their own questions as well as from other peers, while keeping focused on content delivery by the instructor.

6.2.4 MOCCA: Requirement 4: Review breaks

As learners have a limited capacity of receiving and storing information [WK07]. MOCCA introduces the concept of review breaks. On the one hand to refresh student learning capacity, on the other hand to be used for reviews by the moderator and the instructor. This concept should synchronize the instructor and moderators about common issues the students are facing. The instructor should be provided with useful questions and answers to adjust the focus of lecture content and therefore ensure key aspects are properly transferred and understood by students. Typically, review breaks are seen as scheduled events but if moderators are able to detect increasing numbers of questions by specific lecture topics, a review break should be introduced to refine lecture material and instructor explanations.

6.2.5 MOCCA: Requirement 5: Internet access

To ask questions, students should be able to access the internet to use the provided AMATI framework. Students have the minimal requirement to have a device with internet connectivity at hand in order to ask questions via the digital communication channel. If students are not participating in the lecture hall, they can use any device with internet access to view the information shown on the additional content projector as described in Subsection 6.2.3.

6.2.6 MOCCA: Requirement 6: Lecture livestream

Dealing with more than 1000 students for a single course often implies the use of multiple lecture halls as typically universities do not have the resources to host all students in a single lecture hall. Therefore other means of knowledge delivery are needed. We suggest the use of a lecture live-stream which should be made available online for enroled students to allow them to participate from remote locations.

Chapter 7

Analysis

> The most important single aspect of software development is to be clear about what you are trying to build.
>
> Bjarne Stroustrup

Based on the described scenarios in Section 4.8 in combination with the identified requirements of Chapter 6 for the AMATI framework this chapter highlights the analysis phase during the software engineering process of this dissertation by detailing the analysis model separated in Section 7.1 detailing the *functional model*, Section 7.2 presenting the *object model* and Section 7.3 showing the *dynamic model* based on Bernd Brügge [BD09] as seen in Figure 7.1.
First, this chapter starts with the description of the *functional model* which extracts the key *use cases* from the *scenarios* and *requirements*. Second, based on the *functional model* the *object model* is generated which refines all needed participating objects. Third, the dynamic model is introduced in Section 7.3 detailing four separate activities during the use of the AMATI framework.

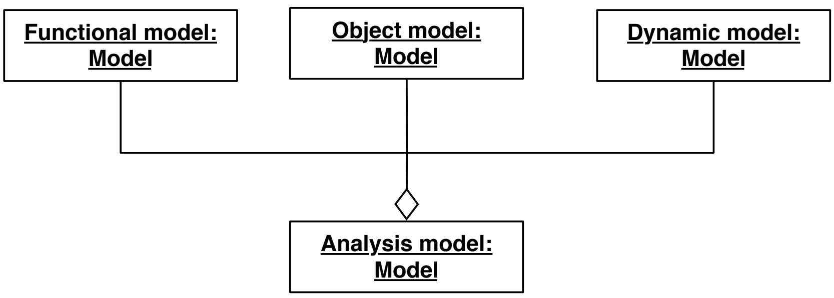

Figure 7.1: Decomposition of the analysis model (UML Instance diagram according to [BD09]

The AMATI framework allows to parallelise student interactions and content delivery flow during lecture hours. This is is achieved by introducing separate threads of communication. Instead of suspending the lecture, question-answer threads started by students are delegated to moderators, while the instructor can focus on content delivery without being interrupted. Figure 7.2 highlights the Adapter pattern used for this principle.

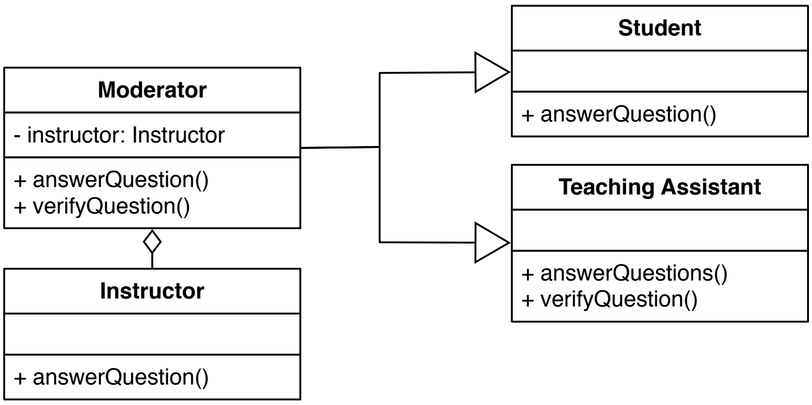

Figure 7.2: Delegation in AMATI by introducing a moderator role (UML class diagram)

7.1 Functional Model

AMATI is based on the MOCCA model seen in Appendix 2 and described in Chapter 4. The resulting functional model focuses on the representation of the functional specifications and the specified requirements of Section 6.1. The functional model is represented in Unified Modeling Language (UML) notation. We are going to highlight the extracted use cases from the scenarios in Section 4.8 by using a UML use case diagram as seen in Figure 7.3 and textually describe four major use cases.

Based on the given visionary scenarios in Subsection 4.8.7 and Subsection 4.8.8 we identified 15 major use cases of which four will be described in this section.

The first use case *Ask Content Question* highlights the key aspects on student interaction with the AMATI framework when students want to participate by asking questions using the provided teaching context support feature in AMATI.

The second use case *Change Context* highlights the incoming change request from a student if the automatically retrieved context from the AMATI framework is attached to the wrong lecture material. This can happen if the instructor already proceeded to another slide of the slide-set and students still have questions regarding material presented before.

The third use case *Mark Correct Answer* describes the verification process, after an answer has been provided by either a student or moderator, this answer will be marked

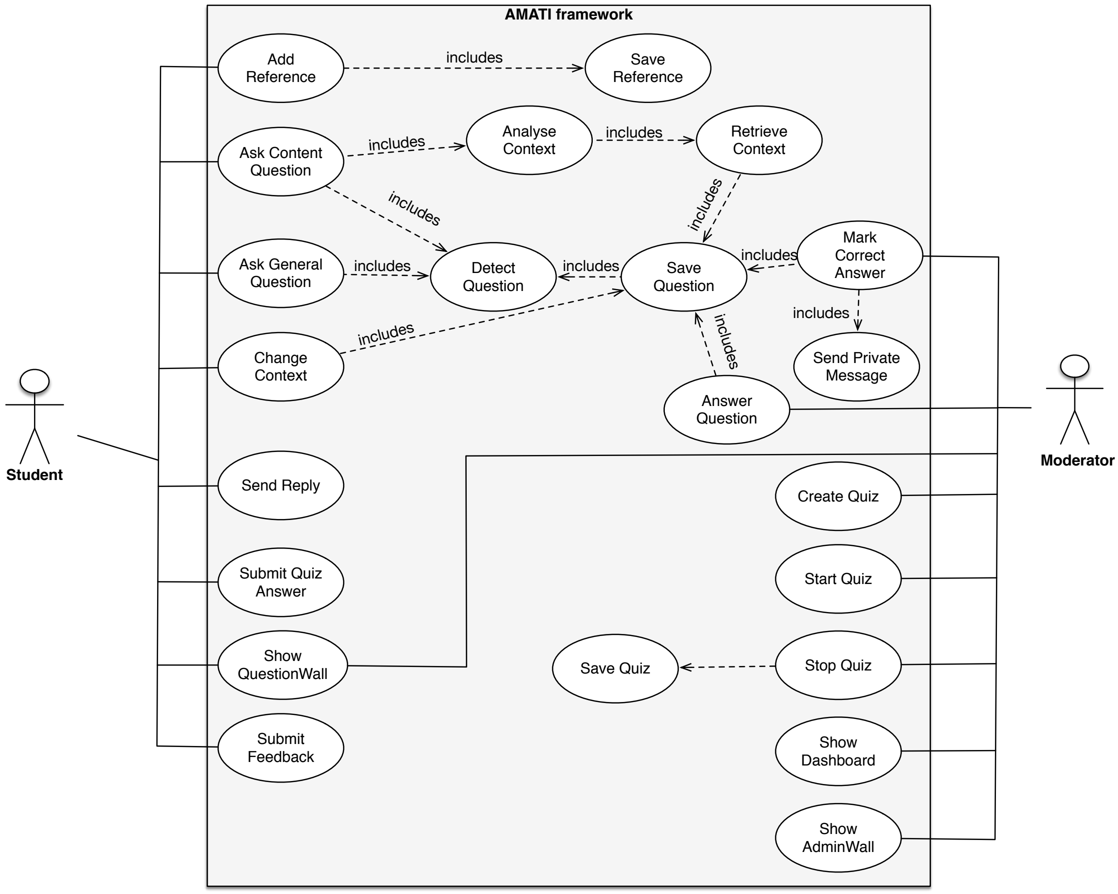

Figure 7.3: Use cases based on the scenarios described in Subsection 4.8.7 and Subsection 4.8.8

as *correct* or *reasonable* for students to enhance their lecture material understanding and will then be presented on the *QuestionWall*.
The fourth use case *Answer Question* focuses on the answering process of a question stated using the AMATI framework. In this use case either a student is able to provide an answer using a peer review mechanism or a moderator provides an answer directly. Based on all use cases, a full elaboration of the analysis object model with respect to the design level can be found in Appendix 2.

Use case name:	Ask Content Question
Initiating actor:	User with role Student of the AMATI framework
Entry condition:	Student has logged onto Slack
Flow of events:	1. The student formulates and sends a *StudentQuestion* using the ***Slack*** chatroom responsible for content related questions. 2. The *AMATI-Chatbot* detects the ***StudentQuestion*** by using its ***QuestionHandler***. 3. The *AMATI-ChatBot* retrieves the teaching context using the ***ContextHandler*** and provides it to the student 4. The *AMATI-ChatBot* saves the *StudentQuestion* to the *AMATI-Repository*
Exit condition:	The student question has been detected and stored by the AMATI-Repository
Special Requirements:	The AMATI-PresenterClient needs to be running in order to retrieve context information.

Table 7.1: Use case: Ask Content Question

Use case name:	Change Context
Initiating actor:	User with role Student of the AMATI framework
Entry condition:	Student entered a question using the AMATI framework
Flow of events:	1. The student realises that the context provided by the ***ContextHandler*** refers to a wrong ***SlideContext*** as the instructor already moved on with the lecture content 2. The student provides new more accurate information in form of a *slideset* and *slide* to the AMATI-ChatBot. 3. The AMATI-ChatBot updates the context accordingly using the ***ContextHandler*** and removes the wrong context 4. The AMATI-Repository is notified by the AMATI-ChatBot using the ***AMATI-Repository-Client*** to update the existing question
Exit condition:	The AMATI-Repository has successfully updated the context of the existing question
Special Requirements:	The AMATI-ChatBot is online

Table 7.2: Use case: Change Context

Use case name:	Mark Correct Answer
Initiating actor:	User with role Moderator of the AMATI framework
Entry condition:	Student question was answered using the AMATI framework
Flow of events:	1. The moderator reviews all answers provided for a specific student question 2. He marks the correct answer using an specific emoji detected by the ***QuestionHandler*** of the AMATI-ChatBot 3. The student is notified via personal message that an answer has been provided 4. The resulting Q&A set is presented to all students using the ***QuestionWall***
Exit condition:	The AMATI-QuestionWall presents the Q&A set
Special Requirements:	The AMATI-ChatBot is online

Table 7.3: Use case: Mark Correct Answer

Use case name:	Answer Question
Initiating actor:	User with Role Student or Moderator of the AMATI framework
Entry condition:	Student entered a question using the AMATI framework
Flow of events:	1. A lecture participant reads through the existing ***StudentQuestions*** provided by fellow students of the course 2. They recognise a ***StudentQuestion*** where they know an answer to 3. They provide an ***Reply*** in form of a ***StudentAnswer*** to be checked by a moderator
Exit condition:	The ***StudentQuestion*** has been updated
Special Requirements:	The AMATI-ChatBot is online

Table 7.4: Use case: Answer Question

7.2 Object Model

There have been four different packages identified in Section 6.1 in conjunction with the use cases identified in Figure 7.3 as seen in Figure 7.4. The packages identified, conclude to the use of a client-server architecture in which the central server responsible for data storage and management is named as *AMATI-Repository*. The *AMATI-Repository* provides the needed backend infrastructure to offer services for typical Create, Read, Update, Delete (CRUD) operations for student interactions. In addition it offers a frontend, which is composed of two different parts, the *ModeratorWall*, and the *QuestionWall*. In addition, there is a software client which connects to the instructors presentation tool called *AMATI-PresenterClient*. In this concrete scenario Microsoft Powerpoint and Apple Keynote was used to retrieve information about the actual teaching context transferring this information to the AMATI-Repository. Finally, the *AMATI-ChatBot* package interacts between the chatroom based application *Slack*, the *AMATI-Repository*, and the *AMATI-Dashboard* package which delivers charts and statistics about their performance to instructors and students. More information about the details of those packages will be described in Chapter 8.

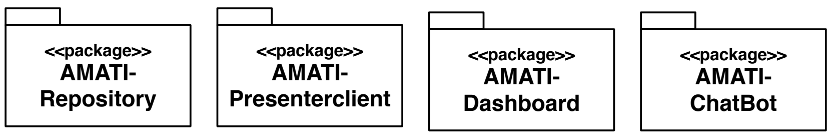

Figure 7.4: Initial packages of the AMATI framework identified based on the functional model (UML packages)

The following subsections will introduce identified class structures of the individual packages including their Separation Of Concerns (SOC) based on Edsger Dijkstra [Dij82]. To highlight key aspects we will follow the Model-View-Controller (MVC) principle introduced by Trygve Reenskaug [Ree79], which has been reformulated and generalised by Ivar Jacobsen [Jac93] using the UML stereotypes entity, boundary, and control as seen in Figure 7.5.

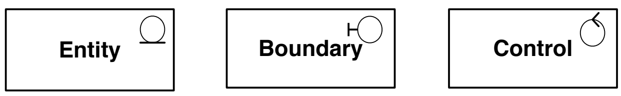

Figure 7.5: UML: Stereotype declarations for entity, boundary and control objects

7.2.1 AMATI-Repository

The AMATI-Repository is the foundation of the AMATI framework. It stores the identified *entity objects*, communicates with the *AMATI-ChatBot* and *AMATI-PresenterClient* over its *boundary objects* and provides data access for the *AMATI-Dashboard* using its *control objects*. This subsection will address each of the entity, boundary and control objects identified based on the functional model of Section 7.1 and its use case definitions of Figure 7.3.
The *DataItem* as seen in Figure 7.6 used as an abstract data type that denotes the ability to exchange all belonging entity objects using a defined data interchange format for example the Javascript Object Notation (JSON) or Extensible Markup Language (XML) allowing marshalling and demarshalling of information before and after transfer. For this reason the same class specifications are going to be used for the *AMATI-ChatBot* as well as the *AMATI-PresenterClient* to allow simple data exchange between the different packages.

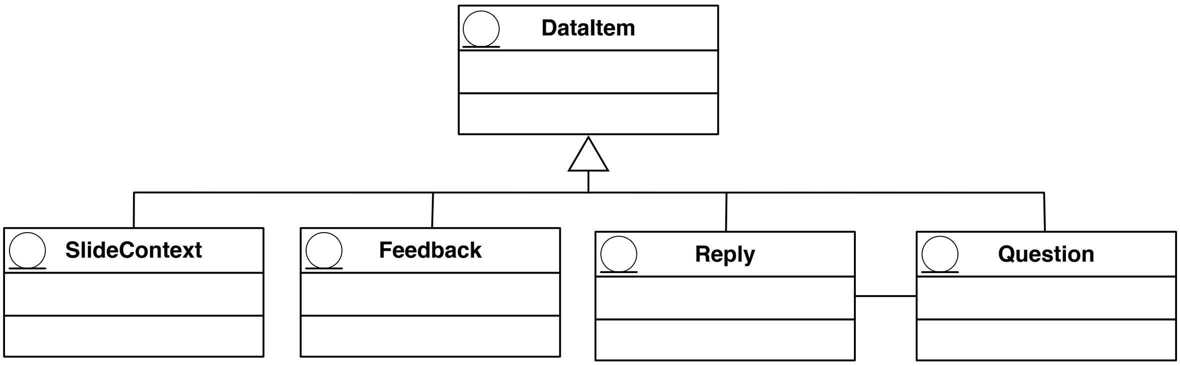

Figure 7.6: Entity Object DataItem of the AMATI-Repository (UML class diagram)

The *SlideContext* definition describes a class which holds all information about a specific teaching context in form of either Microsoft PowerPoint slides, Apple Keynote slides, or PDFs. The SlideContext stores the *slide-set* as well as the *number of the slide* in addition to a *file path* where an image of the context is stored on the *AMATI-Repository*. This collates the *Slide* and *SlideSet* classes defined in Figure 3.11 into a single class. In this dissertation we apply the term context awareness based on Bill Schilit [SAW94] to teaching as follows:

> “ Context aware teaching information include all processes and information provided at a specific time and location based on goals of the instructor and the needs of the learner during a lecture or an exercise. Context aware teaching information is a discrete unit of knowledge including the mapping to its relevant lecture material. This unit can be in the form

of clarifications of lecture content, references to other existing teaching material or additions to teaching content. ”

The *Feedback* class holds all information on student feedback provided via the *AMATI-ChatBot*. Student feedback can be any text send with a pre-defined command to the *AMATI-ChatBot* as a private message.
The *Reply* is an abstract class which denotes that replies can be either in the form of an *ModeratorAnswer* or an *StudentAnswer*. Depending on the different sub type, the *AMATI-ChatBot* can handle certain requests regarding this data differently by using the defined hierarchy in Figure 7.7.

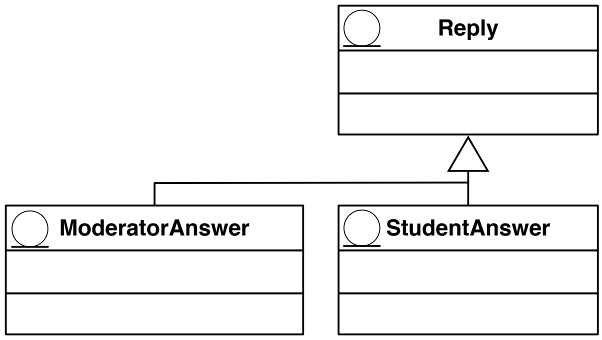

Figure 7.7: Entity Object Reply of the AMATI-Repository (UML class diagram)

The *Question* class is used as an abstract super class which can be specialised in *TeacherQuestion* and *StudentQuestion* instances as seen in Figure 7.8. When students phrase a question using the chat room, the *AMATI-ChatBot* listens for *StudentQuestion* occurrences, pulls the according teaching context in form of a *SlideContext* and stores the data inside the *AMATI-Repository*. The *TeacherQuestion* class allows the instructor to generate questions in form of a quiz to poll students existing knowledge.

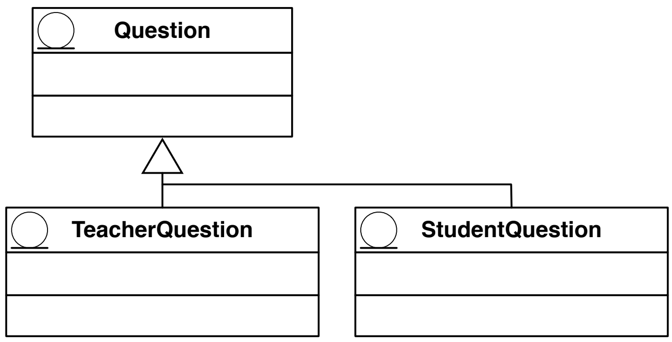

Figure 7.8: Entity Object Question of the AMATI-Repository (UML class diagram)

The *User* definition holds all important user information to map a chat room user to their questions as well as answers. The AMATI framework however does not collect or store any person related information despite of the email address the user registered with and a unique username which students are able to define by themselves allowing pseudo-anonymity when registering for the *Slack* chatroom. Attached to the *User* definition of our systems we keep record of questions asked and answers provided. All those information are stored in the *Score* definition as seen in Figure 7.9.

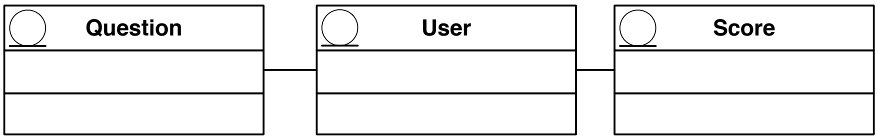

Figure 7.9: Entity Object User, Question and Score of the AMATI-Repository (UML class diagram)

In addition to the *entity objects* described, the *AMATI-Repository* provides an *CommunicationInterface* to communicate with the *QuestionWall* which presents completed *knowledge item* sets in realtime to the student audience. This allows the *AMATI-ChatBot* to retrieve and store teaching information in the form of *Questions*, *Replies* and *Feedbacks*. In addition the *CommunicationInterface* allows the moderators to use the *ModeratorWall* which eases the review process of all open questions including their context and provide answers without the need of using the *Slack* chat platform for the answering process. Finally the *CommunicationInterface* allows the *PresenterClient* to connect and update the teaching context in realtime based on the status of the presentation the instructor is using. Figure 7.10 denotes all entrypoints to be used for the different *CommunicationInterface* clients.

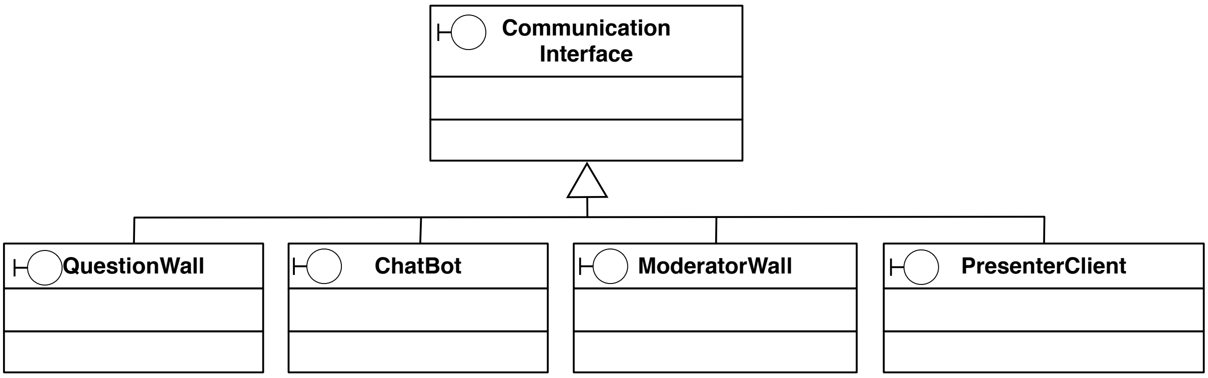

Figure 7.10: Boundary Objects of the AMATI-Repository (UML class diagram)

The *control objects* used by the *AMATI-Repository* handle the different incoming requests of the *CommunicationInterface* using the *CommunicationController* as well as the *StorageController* to store all data sets in an according database handling read and write permissions based on roles of the users communicating with the *CommunicationInterface*.

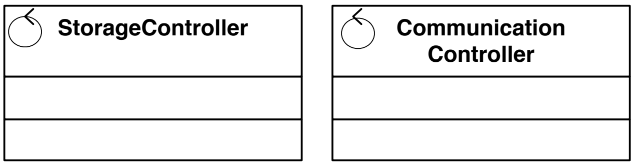

Figure 7.11: Control Objects of the AMATI-Repository (UML class diagram)

7.2.2 AMATI-PresenterClient

The *AMATI-PresenterClient* is used by the instructor and automatically detects the given presentation tool, being either Microsoft PowerPoint, Apple Keynote or a PDF presentation. To provide the context to learners it automatically creates screenshots of the running presentation, uploads the images generated to the *AMATI-Repository* and detects any slide changes while an instructor is giving a presentation. To transmit the data it uses the same *SlideContext* data item as described in Subsection 7.2.1 to transfer the needed information to the *AMATI-Repository*. As the *AMATI-PresenterClient* does not need any additional entity objects, it uses the *DataItem* and *SlideContext* object as seen in Figure 7.12.

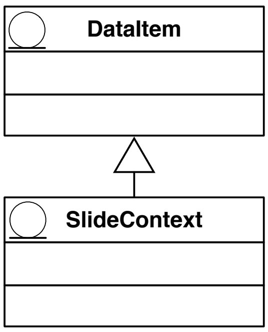

Figure 7.12: Entity Objects of the AMATI-PresenterClient (UML class diagram)

In addition to the entity objects identified the *AMATI-PresenterClient* needs to communicate with the *AMATI-Repository*. The communication established by the use of the provided *CommunicationInterface* from the *AMATI-Repository* in conjunction with a provided client stated as *AMATI-Repository-Client*. In addition to the boundaries to external packages the *AMATI-PresenterClient* also offers a Graphical User Interface (GUI) defined as *PresenterClientUI* as seen in Figure 7.13, which allows to control the communication in regards to uploading slides as teaching context and allowing slide updates while running an instructor presentation.

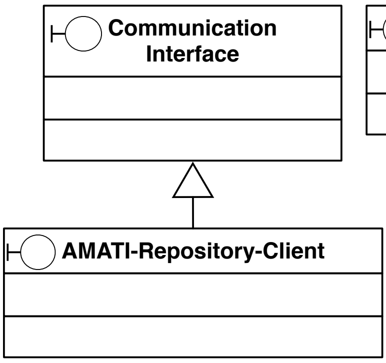

Figure 7.13: Boundary Objects of the AMATI-PresenterClient (UML class diagram)

Handling all the data transmission and updates the GUI elements is done using several control objects as seen in Figure 7.14. The *PresenterViewController* handles the SOC using the MVC design pattern [Gam95]. In addition, the *PresentationDetector* checks if there are any instances of Microsoft Powerpoint, Apple Keynote or an PDF reader running with open documents, while the *PresentationLiveUpdater* initialises the upload of images as well as updating the *SlideContext* data on the *AMATI-Repository*.

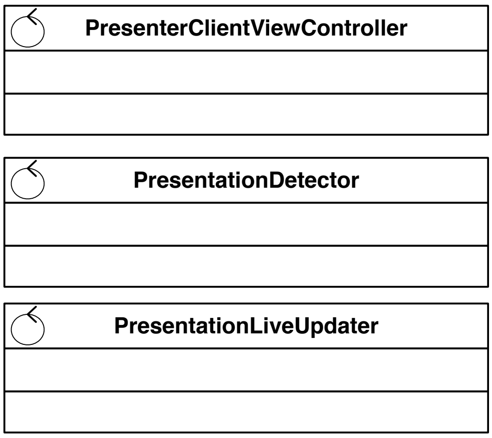

Figure 7.14: Control Objects of the AMATI-PresenterClient (UML class diagram)

7.2.3 AMATI-ChatBot

The *AMATI-ChatBot* can be seen as the link between the *AMATI-Repository* package and the chat platform *Slack*[1] which is used for communication. The AMATI-ChatBot

[1]http://www.slack.org

listens for incoming student questions, handles the retrieval of teaching context from the AMATI-Repository, allows instructors to start teacher quizzes, detect student answers and forwards the moderator answers as personal messages to students and presenting it on the *QuestionWall*.
As the different AMATI packages intend to exchange data based on a client-server architecture, the *AMATI-ChatBot* uses the same entity objects as the *AMATI-Repository*. The transferable data objects defined as *DataItem* should be able to be serialised and deserialized in the same way before and after transmission as seen in Figures 7.6, 7.7, 7.8 and 7.9.
As the *AMATI-ChatBot* is designed as a daemon while using the *Slack* chatroom platform as boundary object for users and the *AMATI-repository* for data storage, the boundary objects of the *AMATI-ChatBot* are connectors to the two different package in the form of the *AMATI-Repository-Client* and a *Slack-Client* as seen in Figure 7.15.

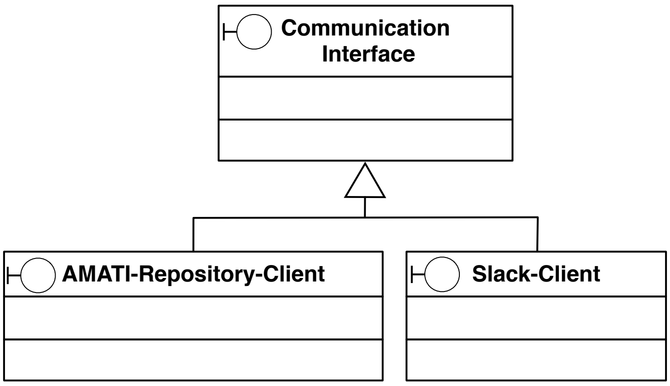

Figure 7.15: Boundary Objects of the AMATI-ChatBot (UML class diagram)

The control objects of the *AMATI-ChatBot* handle three major tasks, the *QuizHandler* allows the creation of teacher quizzes, their execution as well as their output generation while the QuestionHandler is in charge of detecting, storing, and modifying questions based on the *Slack* chatroom user input. The *ContextHandler* keeps track of context changes based on different states of the chatroom, in particular the state of teacher quizzes executed which are elaborated further in Chapter 8.

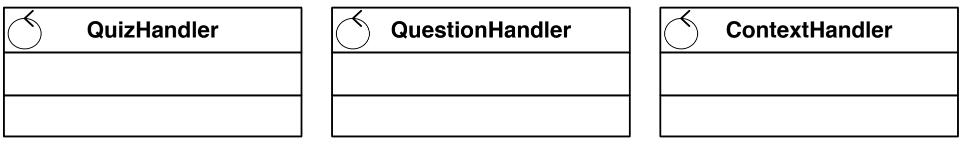

Figure 7.16: Control Objects of the AMATI-ChatBot (UML class diagram)

7.2.4 AMATI-Dashboard

For the AMATI-dashboard an open source solution has been identified and will be used. *Metabase*[2] is an open-source software solution capable of rendering data as charts based on user input queries. For the use of Metabase many different database connectors are available and it provides a query builder which is based on end-user programming principles. This allows to create diagrams and dashboards from different databases quickly without implementing any additional code despite of formulating the queries for polling the existing database. This allowed a swift approach to data analysis and comparison between the different case-studies of EIST in the summer semester 2017 and summer semester 2018 as seen in Figure 7.17. In addition, data analysis for the individual EIST summer semester 2017 and summer semester 2018 course has been created as seen in Figure 7.18.

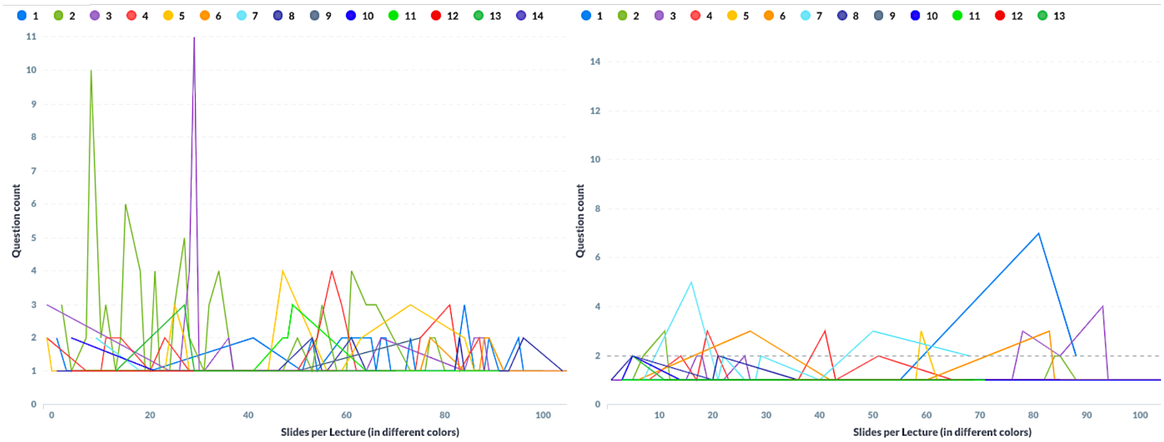

Figure 7.17: Distribution of questions per lecture and slide using the AMATI-Dashboard

[2]https://metabase.com

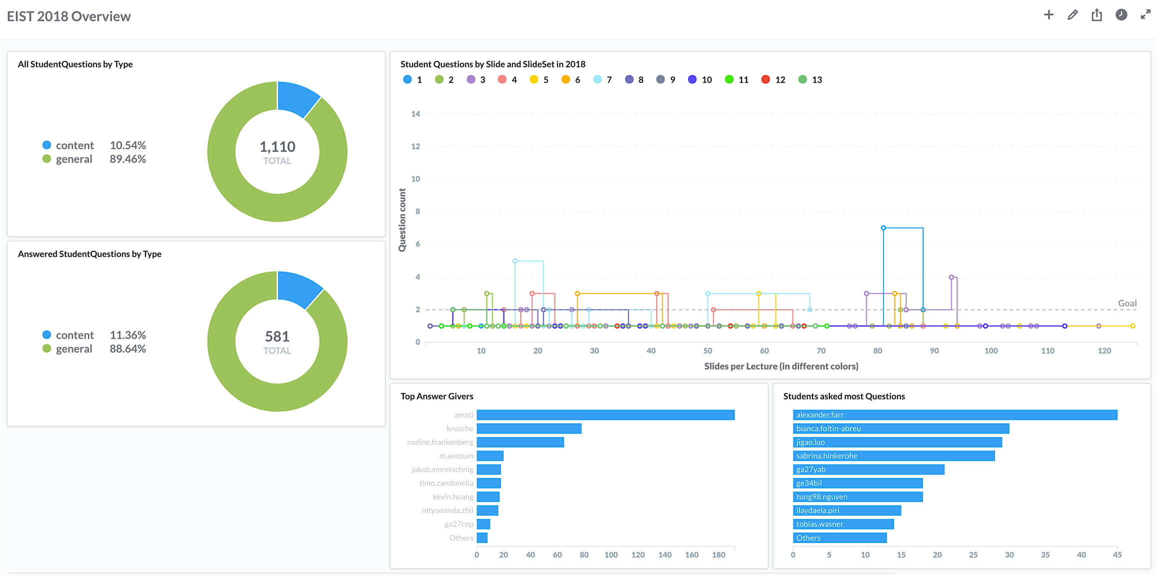

Figure 7.18: A typical snapshot of the AMATI-Dashboard, highlighting the number of questions per semester, active students and active moderators.

7.3 Dynamic Model

This section describes the four packages of the AMATI framework (AMATI-Chatbot, AMATI-PresenterClient, AMATI-Repository and the AMATI-Dashboard) and their interactions using UML activity diagrams.

7.3.1 Activity A1: Student asks Question

When a student asks a question using the Slack chat platform the AMATI-Chatbot package detects the given question and retrieves the according context information provided from AMATI-Repository. The AMATI-Repository is provided with the according context by using the *AMATI-PresenterClient* which submits the existing Microsoft Powerpoint or Apple Keynote presentation to the AMATI-Repository and provides updates on any slide activities done by the instructor. The full activity is shown as a UML activity diagram in Figure 7.19.

7.3.2 Activity A2: Moderator provides and verifies a given Answer

When a moderator provides an answer to a given question using the chatroom platform, the AMATI-Chatbot detects the given answer as a reply to the regarding question. This reply can be provided by a moderator as well as in a peer instruction approach as all replies to questions are detected. To verify an answer provided by either a student or a moderator, the answer needs to be marked as correct by adding a verification label onto the answer. This verification label allows the *AMATI-Chatbot* to detect a

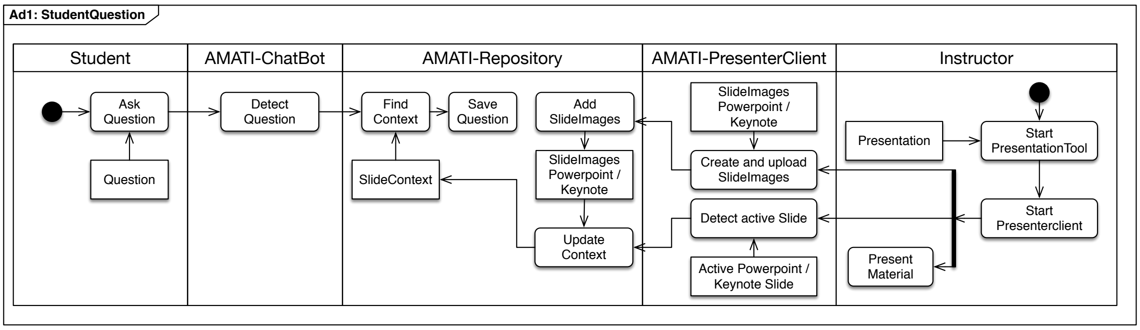

Figure 7.19: Activities and Participating Objects for the Activity *Student asks Question* (UML activity diagram)

verified answer and update the *knowledge item*. This *knowledge item* is then presented on the *AMATI-QuestionWall* and the student providing the question is informed via personal message about an existing answer to his or her question. The full activity is shown as a UML activity diagram in Figure 7.20.

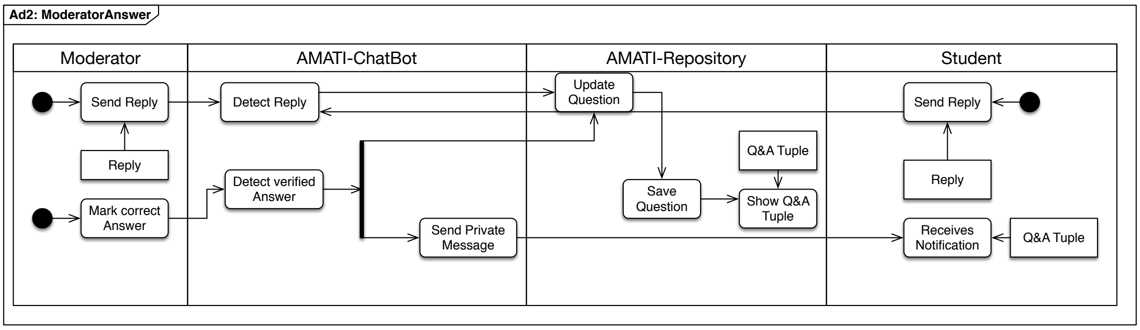

Figure 7.20: Activities and Participating Objects for the Activity *Moderator verifies Answer* (UML activity diagram)

7.3.3 Activity A3: Moderator generates Question-Answer report

When completed *knowledge items* are available the moderator is able to generate a PDF report for each individual lecture containing all *knowledge items* regarding this particular lecture unit. This allows to handout reports as additional teaching material to be combined with the traditional lecture material as seen in Figure 7.21.

7.3.4 Activity A4: Instructor accesses AMATI-Dashboard information

When a lecture unit is over the instructor and moderator are able to review existing teaching questions and their corresponding answers. Student questions can be categorized based on a chronological order to review the existing teaching material, which

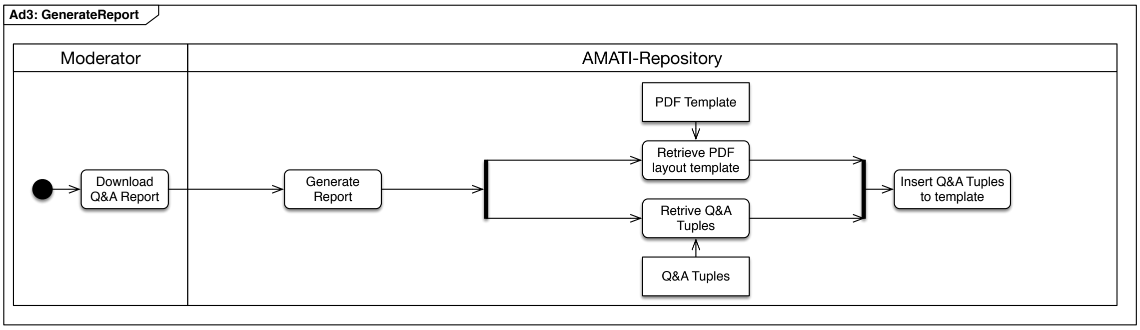

Figure 7.21: Activities and Participating Objects for the Activity *Generation of Reports* (UML activity diagram)

allows the teaching staff to analyze the number of questions occurred during certain teaching units and in even more detail to certain lecture slides. The full activity is shown as a UML activity diagram in Figure 7.22.

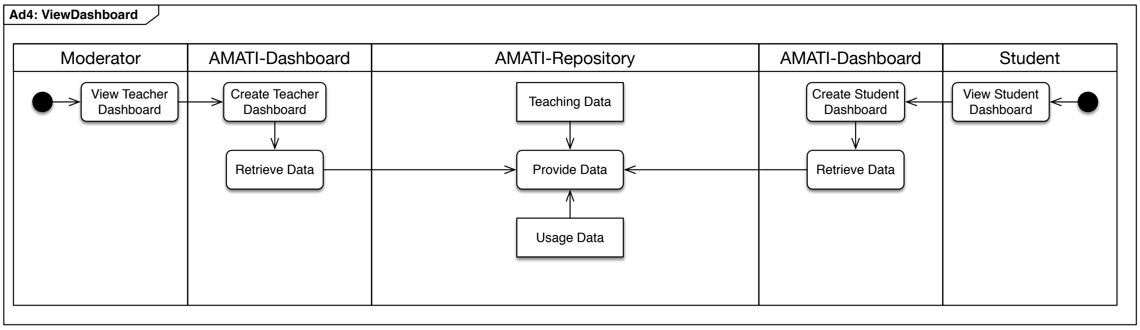

Figure 7.22: Activities and Participating Objects for the Activity *Inspecting the AMATI-Dashboard* (UML activity diagram)

Chapter 8

System Design

> You can build your own things that other people can use. And once you learn that, you'll never be the same again.
>
> Steve Jobs

During the development of the AMATI framework four different packages have been identified in Section 7.2. In Section 8.1 the identified packages are decomposed to subsystems described in Figure 8.1. Section 8.2 describes the needed hardware mapping in order to run all subsystems on specific hardware components. After the completion of the hardware mapping, the reuse of existing software patterns according to Erich Gamma [Gam95] is evaluated to promote reuse, flexibility and scalability of the AMATI framework. The resulting object design of the AMATI framework can be found in Appendix 2.

8.1 AMATI Subsystems

This section highlights the identified components of the AMATI framework and maps them to their regarding subsystems based on the findings Section 7.2 in particular based on Figure 7.4. The result can be seen in Figure 8.1 while the following subsections describe each of the components identified in more detail. The reasoning for the separations chosen is explained in the according components. The software dependencies that are presented were selected with the focus on open source software.

8.1.1 Context Aggregation Component

To accurately capture context during a presentation a small software called *PresentersClient* is deployed on the computer running the presentation in either Microsoft PowerPoint[1] of Apple Keynote[2]. This software automatically detects the current

[1] `https://products.office.com/de-de/powerpoint`
[2] `https://www.apple.com/de/keynote/`

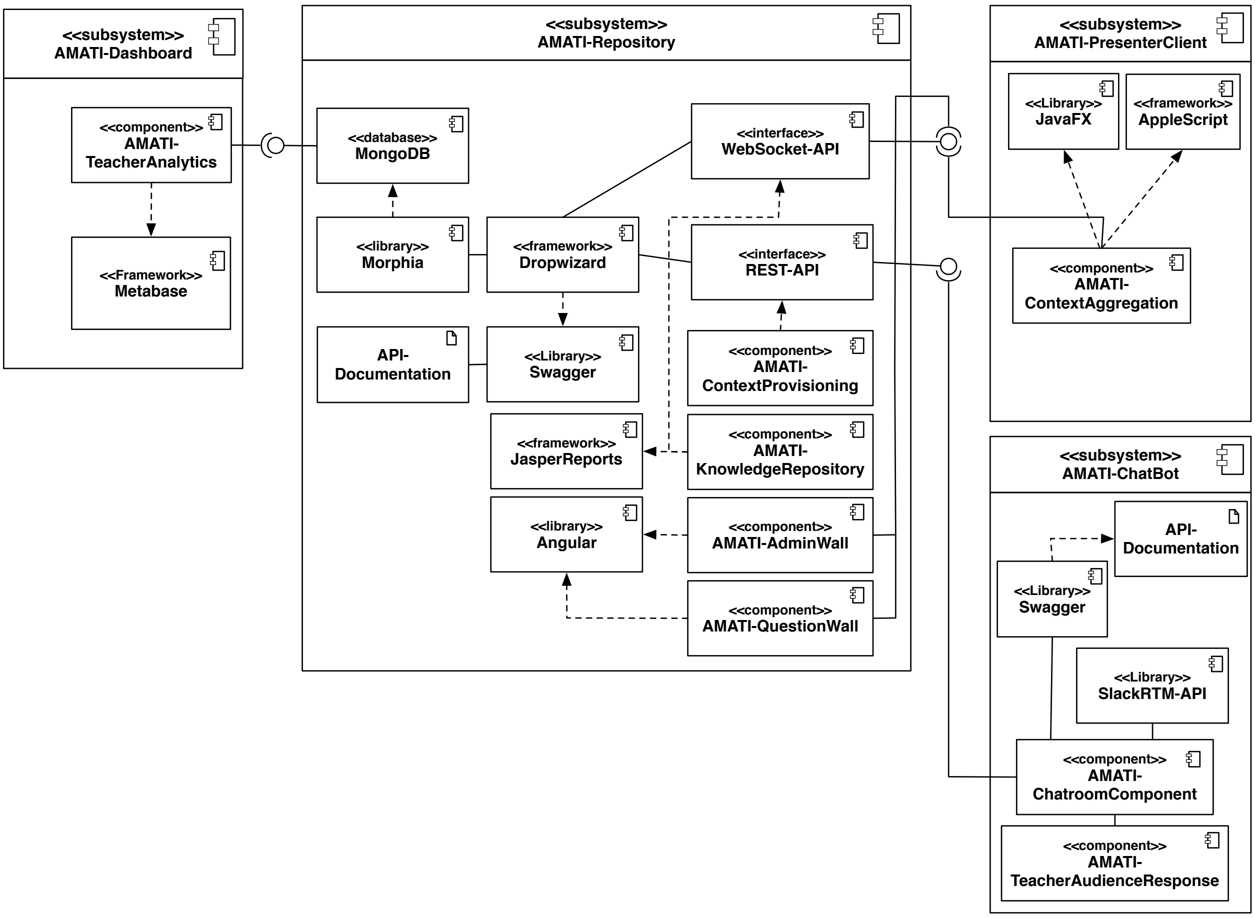

Figure 8.1: Subsystem decomposition of the AMATI framework (UML component diagram)

active slide information. This includes *slide number* and *presentation name.* When connecting to the *AMATI-Repository* screenshots of the individual slides are generated and transferred to the server. This allows tracking of the ongoing presentation.

8.1.2 Context Provisioning Component

The *AMATI-Repository* is responsible for providing all stored information including context information. All the information are going to be passed via a Representational State Transfer (REST) Application Programming Interface (API) to the *AMATI-PresenterClient*, the *AMATI-Dashboard* as well as the *AMATI-Dashboard* in form of integrations. It serves as a central data hub for all other components and ensures data integrity. It also handles data flow between the other components.

8.1.3 Chatroom Component

We used *Slack* as chat room component to serve as a central point for question asking and answering. A slack bot integration connects to the chat rooms via a real time messaging API provided by *Slack* (*Slack RTM API*[Sla17]). The bot integration receives all messages sent in the channels and automatically detects questions by looking for question marks in messages. This component runs on a seperate server and therefore is available during and after lectures. We make use of *Slacks* new feature called *threads* to keep the structure of question channels clear and allow for discussions to be grouped together. We encourage the use of these threads by immediately opening a new thread when a question is posted. An example of such a thread can be seen in Figure 8.2.

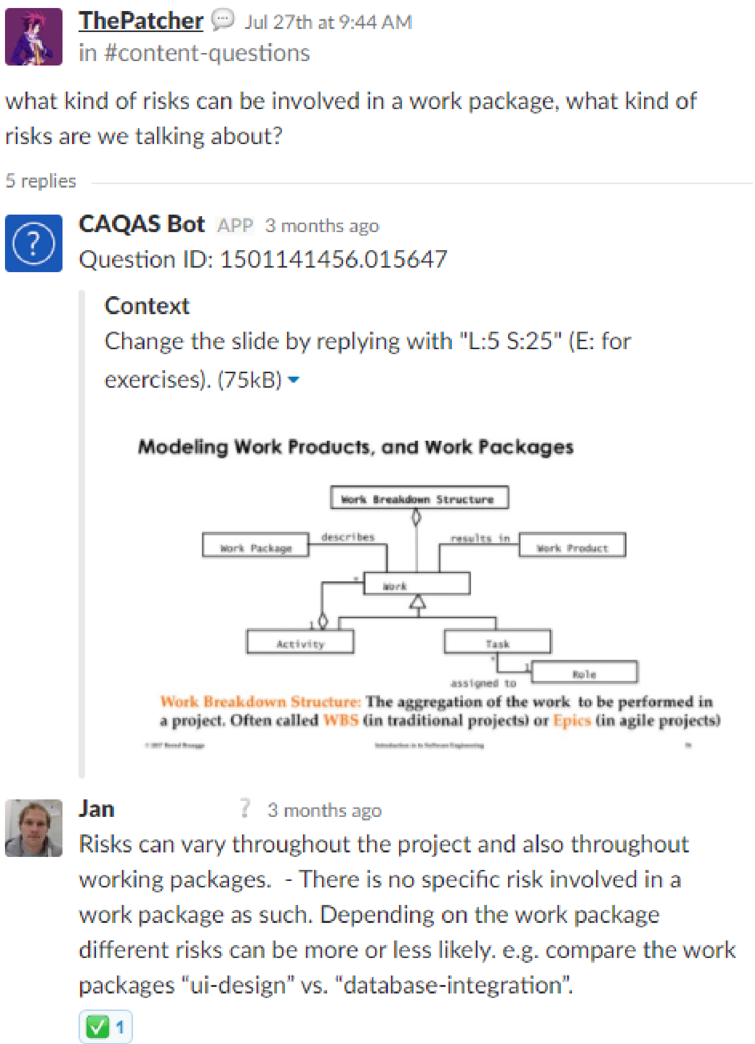

Figure 8.2: A communication thread with provided *knowledge item* using the AMATI-ChatBot and *Slack*

8.1.4 QuestionWall Component

Answers given during lectures are shown on a secondary projector in the lecture hall as soon as a satisfying answer has been locked in. This allows students to follow up on questions while focusing on the lecture content. The *AMATI-QuestionWall* updates itself automatically the moment the moderator decides to share a completed *knowledge item* set. It also provides options to filter stated questions by certain categories namely: general questions for lecture organization and content-related questions for in-class content. This allows students to focus on content relevant information during lecture participation time. In addition to reviewing the *knowledge item* sets provided, it is possible for students to review the full discussion of the answering process. This allows students to trace references and explanations if the answer alone is not sufficient for clarification. A screenshot of the question wall highlighting the lecture context, and the associated *knowledge item* set can be seen in Figure 8.3.

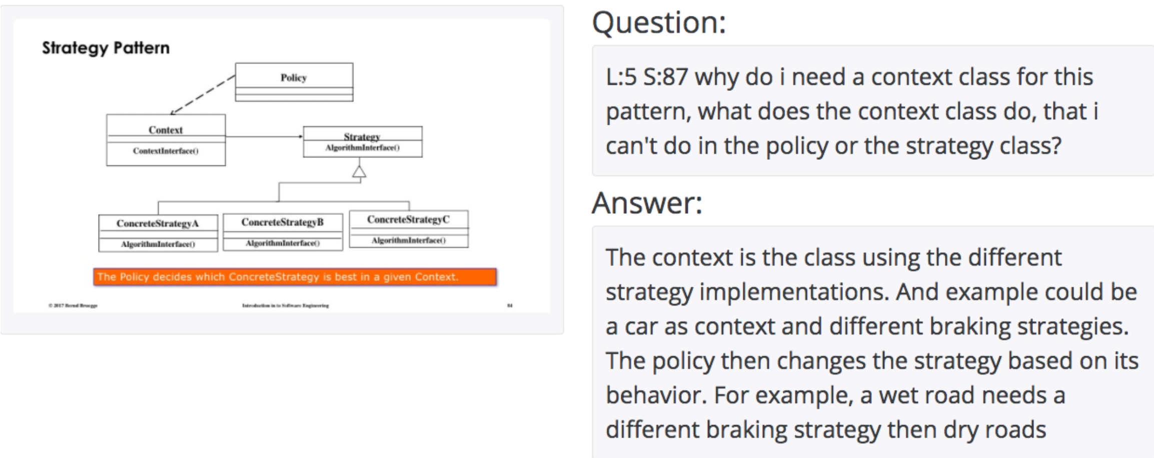

Figure 8.3: Knowledge item presented using the AMATI-QuestionWall

Students can choose to open the question wall on their own devices, as it is publicly available. This allows students to set a personal filter for question-answer-context sets to be displayed, in addition students can use the question wall while not participating live in the lecture but via live stream.

8.1.5 ModeratorWall Component

During lectures, moderators are focusing on handling all incoming questions, by providing answers, marking correct answers from peers or even removing messages which are not contributing towards learning. As a chatroom is not intended to list all open and closed questions detected by AMATI the *ModeratorWall* was created. The ModeratorWall allows moderators to see all open and closed student questions, provide answers directly, and verify existing student answers without the need of using the *Chatroom Component*.

8.1.6 Knowledge Repository Component

Since the *QuestionWall* component provides students only with the last 10 questions asked, new means of storing and providing a knowledge repository for studying purposes has to be introduced. The AMATI framework allows students to access generated *knowledge item* reports in the form of portable document format (PDF) files for each session. The *knowledge item* sets provided contain their relevant teaching context and are sorted in the order in which questions occurred. In addition to the Question-Answer reports generated for content related questions, an additional report for general questions is compiled containing organizational questions that have been asked during the course.

8.1.7 Teacher Analytics Component

In conjunction to the features mentioned above, AMATI offers an analytics dashboard for teachers to highlight important statistics in various areas. The dashboard provides the teacher with comprehensive information such as tool participation rate, questions and answers given including their context or the average time to answer questions needed by the moderator. Figure 8.4 shows a plot of questions asked per slide and lecture, detailing a specific outlier in lecture 3, Slide 29 as there has been a disproportionately high number of questions asked for this single slide in particular. These insights can provide the instructor with new means of lecture analytics and content revision. To provide a dashboard in AMATI an open source framework named *Metabase* [Met17] has been used to easily configure interesting data plots for different needs. Therefore it is possible to enhance and modify existing dashboards to retrieve even more detailed information if necessary.

8.1.8 Teacher Audience Response System Component

AMATI also provides the possibility to the teacher to query the student corpus with specific content-related questions to receive an impression of the knowledge state of the student audience. This can be done by sending a question via Slack in conjunction with providing different answer possibilities. Those answer possibilities can than be send to the *AMATI bot integration*, which takes care of the summarization. Results will be presented on the *QuestionWall* plotting the student votes graphically.

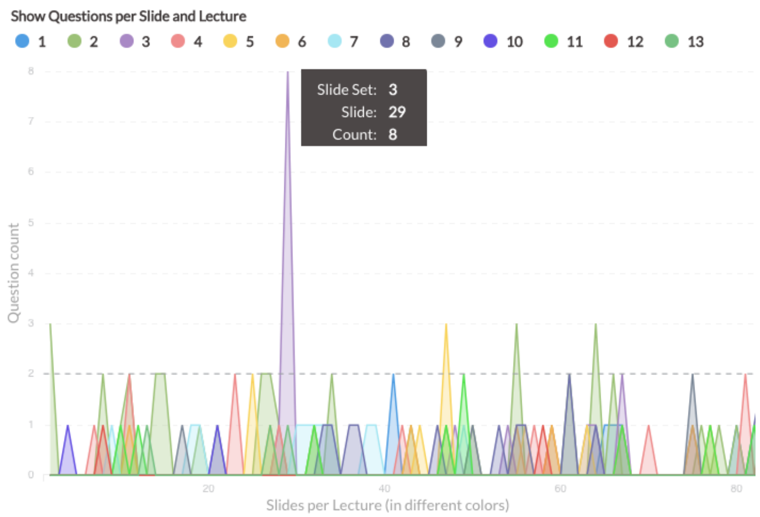

Figure 8.4: Number of Questions asked per slide and slide-set using the AMATI-Dashboard

8.2 AMATI Hardware mapping

Based on Figure 8.1, the 4 subsystems have been separated into three different hardware parts as seen in Figure 8.5. The *MongoDB* database used is stored on a dedicated database server, while the *AMATI-ChatBot*, *AMATI-Repository* and *AMATI-Dashboard* share a common application server. As Java has been selected as the programming language, the application server can be hosted in all major operating systems available. For the *AMATI-PresenterClient* the use of the Mac OS operating system is required as the *AppleScript* framework is used to allow easy access to Microsoft Powerpoint, Apple Keynote and PDF preview tools by using a centralized interface.

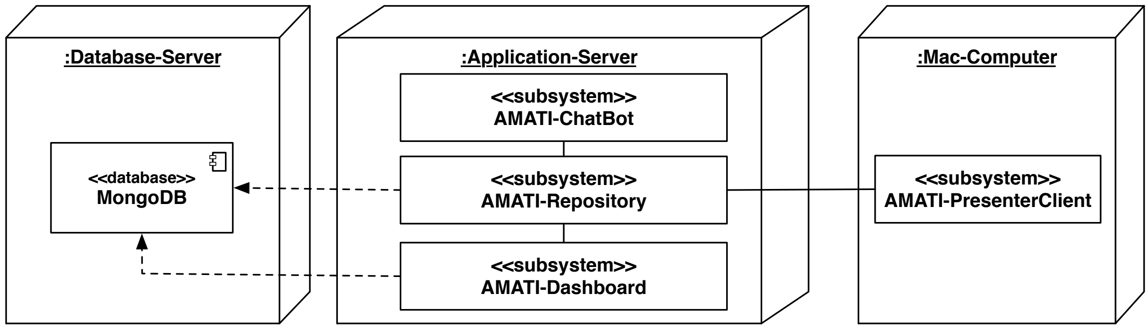

Figure 8.5: Hardware Software mapping for the AMATI framework (UML deployment diagram)

8.3 AMATI Design Pattern Usage

Based on the structure of the subsystems shown in Figure 8.1 and their according analysis model in Section 7.2 the following software patterns have been identified and will be used during the object design as seen in Table 8.1.

Software Pattern categories	Applied Pattern	Usage
Structural Pattern	Model-View-Controller Proxy State	AMATI-PresenterClient AMATI-Repository AMATI-ChatBot
Behavioural Pattern	Observer	AMATI-Repository AMATI-ChatBot AMATI-QuestionWall AMATI-ModeratorWall
Creational Pattern	-	-

Table 8.1: Used Software Patterns during the implementation of the AMATI framework

The *AMATI-PresenterClient* uses the JavaFX[3] framework, which allows the creation of modular user interfaces using the MVC pattern by separating the model and control objects from their according view elements using the *FXML* file type specification and a scene builder provided by Gluon[4]. The *AMATI-Repository* uses the *Proxy* pattern to detect if there is an active presentation context available and if there is no *AMATI-PresenterClient* connected. It provides a fallback mechanism showing a template image instead of the context image provided.
The *AMATI-ChatBot* uses the *State* pattern to differenciate between existing states when creating *Teacherquizes* for the student audience. The *QuizHandler* state pattern is detailed in Figure 8.6.

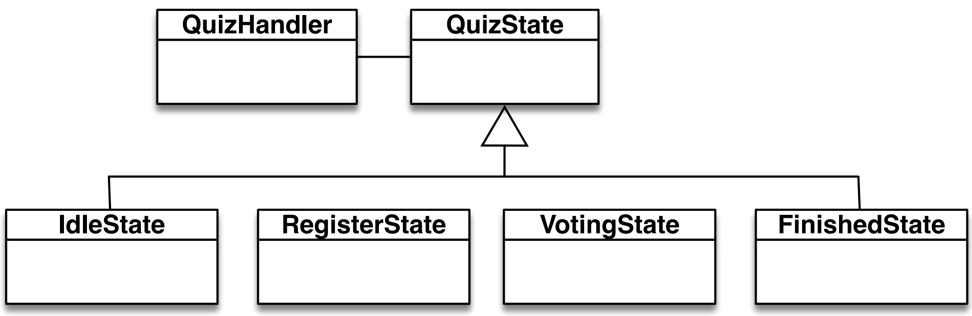

Figure 8.6: QuizStates applying the state pattern for the AMATI-ChatBot (UML class diagram)

[3] https://openjfx.io/
[4] https://gluonhq.com/products/scene-builder/

As data transfer is managed over a REST API and web-socket API as seen in Figure 8.1, we apply the observer pattern in particular for the web-socket connections between the *AMATI-Repository*, *AMATI-ChatBot*, *AMATI-QuestionWall* and *AMATI-ModeratorWall*.

Chapter 9
Case Studies

> Without data you're just a person with an opinion.
>
> W. Edwards Deming

This chapter introduces the three different case studies which have been evaluated between the summer semester 2016 and summer semester 2018 at the TUM.

9.1 Einführung in die Softwaretechnik - Summer Semester 2016

During the summer semester 2016, 1142 students participated in the course EIST. It was a heterogeneous student group as the course is offered to many different degrees as seen in Table 9.1.

Degree	Student enrolments
Computer Science, Bachelor	380
Games Engineering, Bachelor	189
Business Computer Science, Bachelor	184
Commerce, Bachelor	181
Business with Technology, Master	60
Math, Bachelor	32
Other degrees	116
# Students	1142

Table 9.1: Lecture participants by degree during EIST in the summer semester 2016

Due to the massive amount of students enrolled to the subject, the course was offered in three different lecture halls. Therefore the department of applied software engineering (ASE) established a live streaming concept supporting students over different classroom locations, as well as provided an online streaming service using the *livestream.com*[1] platform. More detailed information about the classroom setup can be found in Table 9.2.

Listing	Count
# Overall students	1142
# Tutors	24
# Lectures	21
# Lecture halls	3
# Recording Team	2
# Professor	1
# Teaching Assistant	1

Table 9.2: Students and Teaching personal during EIST in the summer semester 2016

Due to setup of a live streaming service, new means of communication for students during lecture hours needed to be introduced in order to increase interaction from different locations. Therefore, in addition to the existing lecture content management system namely Moodle[2], a new chat platform was introduced to increase communication. The decision of this tool has been made on a base of established standards for industry communication; which led to the selection of *Slack*. The lecture used a single projector for content delivery, a single presenter laptop for the instructor as well as an additional laptop for the moderator as seen in Figure 7.3. The setup for the EIST course of the summer semester 2016 is shown as a UML deployment diagram in Figure 9.1.

[1] `http://www.livestream.com`
[2] `http://www.moodle.org`

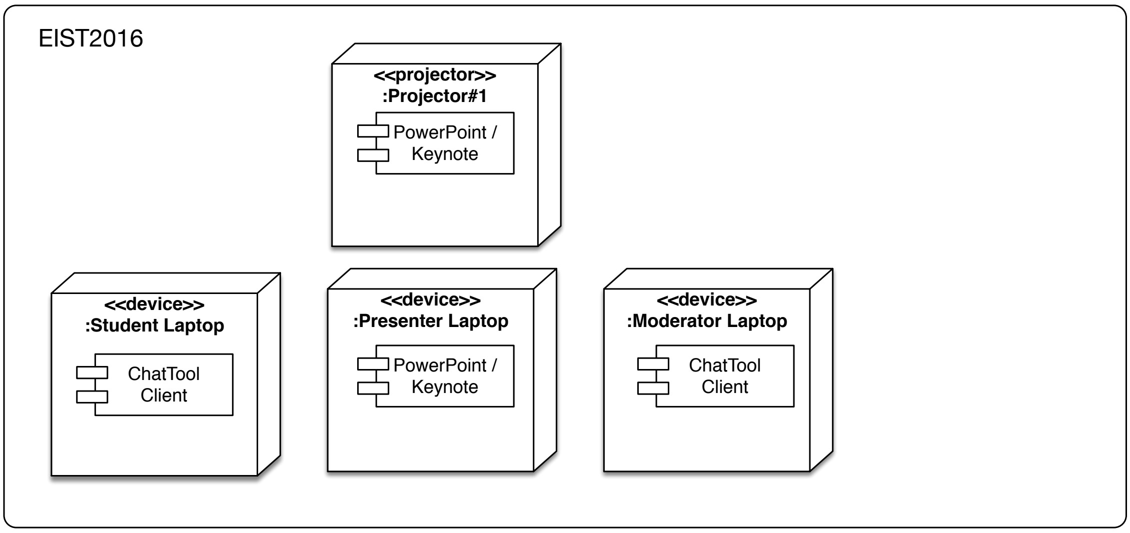

Figure 9.1: EIST 2016 Lecture setup (UML Deployment diagram)

9.2 Einführung in die Softwaretechnik - Summer Semester 2017

During the summer semester 2017, 1431 students participated in the EIST course. This is an increase of 289 students and the student population was showing a heterogeneous state according to student degrees as seen in Table 9.3.

Degree	Student enrolments
Computer Science, Bachelor	380
Commerce, Bachelor	232
Business Computer Science, Bachelor	216
Games Engineering, Bachelor	190
Business with Technology, Master	99
Math, Bachelor	46
Other degrees	127
# Students	1431

Table 9.3: Lecture participants by degree during EIST in the summer semester 2017

A live streaming service was established in the same way as in the summer semester 2016. A change occurred according to the setup of *Slack* being used as a chat platform. Instead of using *Slack* independently from the AMATI framework, an integration has been developed to allow context-awareness in *Slack* as stated in Subsection 7.2.1. More detailed information about the classroom setup can be found in Table 9.4.

The lecture used two projectors, one for content delivery used by the instructor and a second projector to present the *QuestionWall* as described in Subsection 8.1.4. A single presenter laptop was used for the instructor as well as an additional laptop for the moderator as seen in Figure 7.3. The presenter laptop was equipped with the *AMATI-PresenterClient* as seen in Subsection 8.1.1. AMATI also integrated the *Morning Quiz* (see Section 4.2) into *Slack* as a polling mechanism for instructors. A typical setup for the EIST course of the summer semester 2016 is shown as a UML deployment diagram in Figure 9.2.

Listing	Count
# Overall students	1431
# Tutors	44
# Lectures	12
# Lecture halls	2
# Recording Team	2
# Professor	1
# Teaching Assistant	1

Table 9.4: Students and Teaching personal during EIST in the summer semester 2017

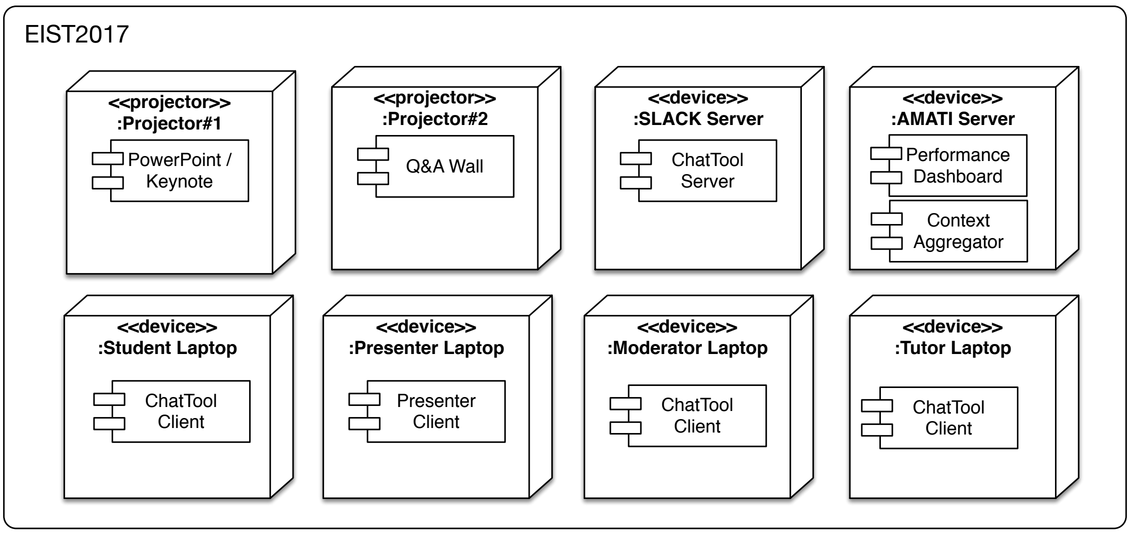

Figure 9.2: EIST 2017 Lecture setup (UML Deployment diagram)

9.3 Einführung in die Softwaretechnik - Summer Semester 2018

The final assessment of the AMATI framework took place during the EIST course of the summer term 2018. As the student population was growing to 1625 enrolled students as seen in Figure 9.5, new means of answering questions needed to be deployed.

Degree	Student enrolments
Computer Science, Bachelor	579
Commerce, Bachelor	299
Business Computer Science, Bachelor	200
Business and Technology, Master	191
Games Engineering, Bachelor	163
Math, Bachelor	29
Other degrees	164
# Students	1625

Table 9.5: Lecture participants by degree during EIST in the summer semester 2018

In addition to the use of three different moderators using *Slack*, in combination with the provided teaching context from AMATI, a new feature was introduced for moderators. This so called *ModeratorWall* helped moderators to answer questions without the need to use *Slack* for the answering process, as the *ModeratorWall* provided all needed information about open questions, context and the possibility to mark correct answers. A list of all lecture participants can be found in Table 9.6. The setup of all devices for the EIST course in the summer semester 2018 is highlighted in Figure 9.3.

Listing	Count
# Overall students	1625
# Tutors	47
# Lectures	12
# Lecture halls	2
# Recording Team	2
# Professor	1
# Teaching Assistant	3

Table 9.6: Students and Teaching personal during EIST in the summer semester 2018

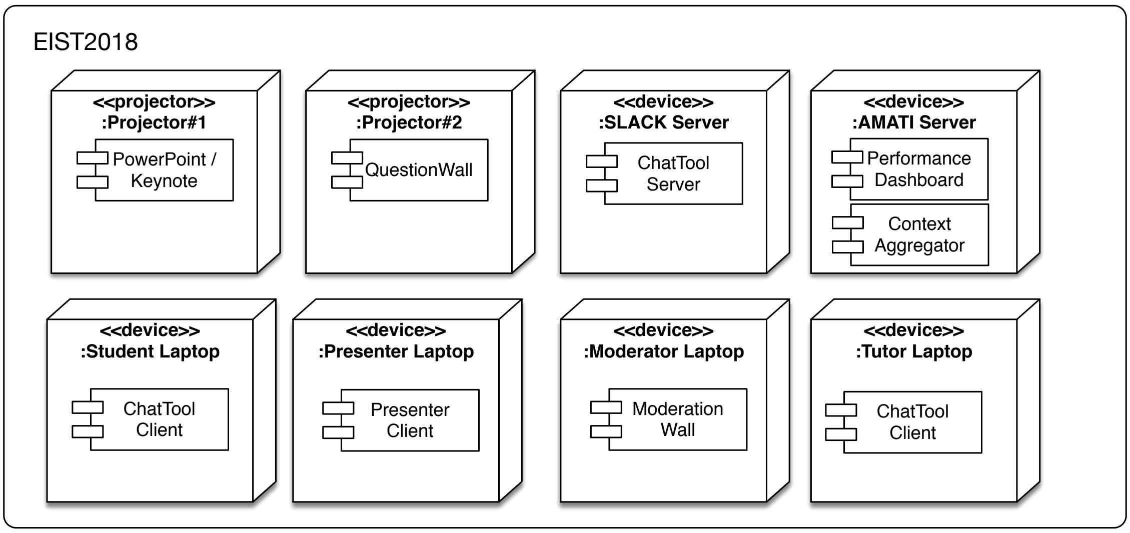

Figure 9.3: EIST 2018 Lecture setup (UML Deployment diagram)

Chapter 10
Evaluation

"The truth is rarely pure and never simple"

Oscar Wilde

This chapter describes the evaluation of the formative research approach specified in Section 1.5, which is shown in in Figure 10.1. We evaluated AMATI and MOCCA and the hypotheses described in Section 1.2 over a period of three semesters using the EIST courses at TUM.

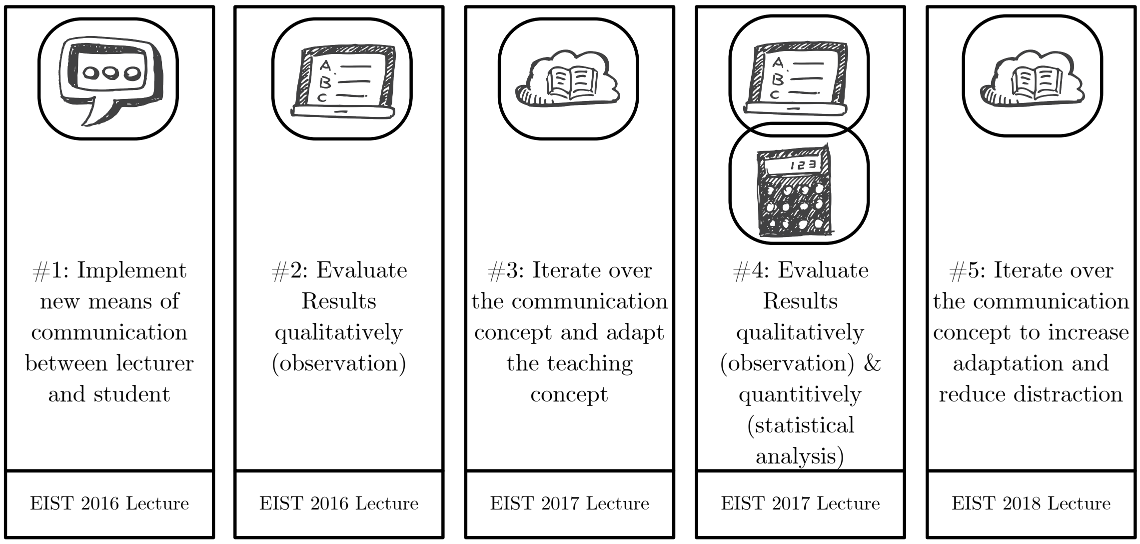

Figure 10.1: Research Approach: A formative and iterative design used on a software engineering foundation course

This evaluation is three-fold. The first section provides a descriptive analysis using two conducted questionnaires during the summer semester 2016 (p=341) and summer semester 2017 (p=226). The second section describes the quantitative analysis based on the data collected while using the AMATI framework in combination with the analysis of student exam performance. The third section of this chapter covers all threats analyzed based on our findings.

10.1 Descriptive Analysis

The descriptive analysis is based on two questionnaires conducted in the EIST course each 30 days before the end of the according summer term 2016 and 2017. The number of participants of the questionnaire can be seen in Table 10.1 contrasting the enrolled students during each of the EIST courses.

questionnaire	full results	partial results	enrolled students	response rate
EIST 2016	238	341	1142	20,8%
EIST 2017	226	309	1431	15,7%

Table 10.1: Number of enrolled EIST students and questionnaire participants of the summer semester 2016 and 2017

The third part of the descriptive analysis was done by analyzing the needs formulated during the summer semester 2016 and 2017 with respect to data collected while using the AMATI framework in the summer semester 2018.
The following sub sections highlight key findings in regards to the questionnaires conducted. We refer to participants as all students that participated during the questionnaire, not the full student population. During the questionnaire of the EIST summer term 2016 we reached a response rate of 20.8% whereas the questionnaire conducted during the EIST summer term 2017 had a response rate of 15.5%. We state our findings in textual description, using a bracket notation referencing the appropriate question-answer tables in the appendix. In Appendix 3 a machine readable version of all questionnaire results can be found.

Case study EIST 16

This first case study was conducted during EIST course of the TUM in the summer semester of the year 2016. This year was special in regards to reaching over 1000 participating students in a single course at the faculty of computer science and therefore forcing the university administration of offer multiple rooms for a single course. This led to the introduction of live streaming services to multiple lecture halls. The repeated introduction of such a teaching environment has been defined as a so called Massive On Campus Course (MOOC) [KG17] and its full definition can be found in Section 1.1.
During the iteration of the summer term 2016 a chat room application *Slack* was introduced to support student-to-teacher interaction. The number of questions and their according categories can be found in Table 10.2. The implicit lecture context during this year was not saved, which means it was not possible to map questions back

to their according lecture material. During the EIST‘16 course students asked a total of 67 questions which have been answered. None of these questions had a reference to context.

Question Type		# Questions
General		14
Content	Context provided	0
	No Context provided	53
Total		67

Table 10.2: Number of Questions asked in EIST‘16 by category

Next to the introduction of *Slack* and MOCCA as a methodology, a student questionnaire was conducted in which 341 students participated providing 238 complete responses. The questionnaire consisted of 32 questions in 4 categories. In the first question group ”General Info” basic data about the participant like field of study and current semester were gathered as well as information about participation and tool use. The second group ”Methodology” provided comparable data to evaluate the change in the MOCCA methodology. It consists of six questions total. The third group ”Live streaming” consists of 6 questions and analyzes student behaviour in regards to live-streaming and the provision of post-processed lecture recordings. The fourth category ”Tool evaluation” contains 11 questions to elaborate the tools provided with regards to ease-of-use and distraction while using them, as well as their usefulness in regards to communication.
When asking our questionnaire participants about their primary lecture attendance type the majority of students (60.08%) stated they used the primary lecture hall for consumption while over a third of the participants (36.13%) already preferred using the provided live-stream over the minority of students that used the second lecture hall provided (3.78%). This is impressive as the live-stream was just introduced in the beginning of the semester [1].
Regarding the introduction of interactive slide adaptions in order to correct mistakes or provide additional information a majority of the questionnaire participants (72.69%) liked this approach either very much or much [2].
Introducing the *Morning Quiz* as a self assessment method for students, an overwhelming majority of questionnaire participants (79.41%) appreciated this new mean of interaction to get engaged into the lecture before starting with new content [3].
As the technical feasibility for on-the-fly lecture customization based on *Morning Quiz* results was tested by Johannes Flemke [Fle15], the majority of participants (60.5%) liked this concept either very much or much on a five point Likert scale [4].

Introducing *Slack* as a communication platform came with the downside of distraction for students. Many participants (31.94%) felt very much or much distracted using the chat platform while following the lecture [5].
The introduction of the moderator role allowed the use of additional persons either teaching assistants or even tutors to answer incoming questions. Nearly half of the participating student population of the questionnaire (44.96%) agreed on that the answers provided are either very much or much useful, where (23.11%) still found the answers provided moderately useful [6].
When participants where asked about the introduction of new features, in particular a gamification approach which allows students to create content related questions and compete with their student peers in form of a quiz duel, more than the half of the student population (53.78%) liked the idea very much or much while more students agreed on that this will be moderately useful (22.69%) [7].
Since AMATI was introduced as a two-way communication in form of student questions and teacher questions, participants have been asked to rate these different communication features. The results regarding the two different features where similar showing very much and much ratings (52.94%) for student questions and very much and much ratings (52.05%) for teacher questions.[8, 9].

Case study EIST 17

The second case study covered the EIST course during the summer semester of the year 2017. In this year the student corpus increased from 1142 students to 1431 students. The addition to EIST'17 was the integration of teaching context into *Slack* by using AMATI. This allows a comparison of collected data to evaluate the impact of context information on student interaction. Additionally, students were given a questionnaire to evaluate their experience with the AMATI framework.
The questionnaire was was filled out by 341 students of which 238 provided complete responses. It consisted of 29 questions in 4 categories. In the first category "General Info" some basic data about the participant like field of study and current semester were gathered as well as information about participation and tool use. The second group "Methodology" consists of 4 questions, with 2 of them directly relating to the use of AMATI. The third group "Tool evaluation" consists of 10 questions detailing on tool usage in addition to lecture setup modifications applying MOCCA. The fourth group "AMATI specific" was used to reflect on different features like the *QuestionWall* or PDF exports introduced using the AMATI framework.
After the introduction of the new context feature using the *AMATI-ChatBot* in combination with *Slack* we compared the recommendation likelihood of using standalone *Slack* (42%) in contrast to AMATI and *Slack* (50%) using teaching context provided

by the *AMATI-PresenterClient*. This denotes that when asking questions for students there is only a little impact using teaching context purely for asking questions for students. This result does not take the generated knowledge-base as well as the additional information provided for moderators into consideration. [11, 12].

When *Slack* was introduced in the summer term 2016, distraction was a big factor as 31.94% of the participants felt very much or much distracted. This is why we introduced the *QuestionWall* feature to students in the summer term 2017. This allowed new means to consume *knowledge item* sets by looking at a separate projector instead of being permanently active in a chat platform like *Slack*. When asking the participants about distraction of the *QuestionWall* in the questionnaire, the majority of students was only slightly distracted (31.42%) or did not feel distracted at all (26.99%) [10].

As the *QuestionWall* feature needed a second projector, the participants were asked whether they feel distracted by following two projectors with different content presented at the same time. In the beginning of the semester nearly half of the participants felt not distracted (46.46%) or slightly distracted (25.22%). When asking about distraction after participating in this course for some weeks, the majority of participants felt not distracted at all (64.16%) or slightly distracted (18.58%). This indicates that students are able to adapt to multiple input signals from instructors. In addition the *QuestionWall* only presented complete *knowledge item* sets which also have relevance to the teaching-context of the instructor. [13, 14].

With regards to the new communication participants slightly preferred AMATI (46.90%) as a way for receiving answers to their questions compared to the professor directly (35.40%) [15].

When asking questions to the professor during the lecture a minority (26.55%) of participants would prefer a direct contact. The majority of participants liked using AMATI (60.18%) to formulate their questions [16].

Since appropriate answers to student questions given in a timely manner can help to digest teaching material, participants have been asked both, about the speed in which answers have been provided, as well as about the quality. The majority of participants (44.69%) stated that answers have been provided in a timely manner while a minority (10.18%) felt their questions took too long to be answered, while nearly half of the participants (45.13%) did not provide any answer at all [17].

With regards to quality the majority (53.98%) felt that the answers provided have been adequate enough to help following lecture content [18].

Finally, participants felt that they stated more questions using AMATI (43.81%) compared to the raise of hand method (23.45%) while a third of the participants did not provide an answer(32.74%) [19].

With regards to exam preparation by providing a *knowledge item* PDF report of all questions phrased and their according answers nearly a third of the participants (27.87%) found these reports useful, whereas 20.80% did not answer this question [21]. The open feedback question received 69 results with 42 of them concerning AMATI. The responses were classified into categories to analyze trends. The classification resulted in 10 categories. Each response was matched to exactly one category. Responses that would fit into multiple categories where split up into several unique responses. The results can be seen in Table 10.3.

Category	Responses
Appreciation	19
Improvement suggestion	5
Tutorial request	5
Bug report	3
Overwhelmed by tools	2
Communication too Cluttered	2
Felt distracted	2
Tools are impractical	2
Dislike of the tools	1
Not satisfied with quality	1

Table 10.3: Classification of open question results from the questionnaire.

AMATI data observations

With the introduction of context the number of questions asked increased by 431% to a total of 356 questions during EIST'17 as seen in Table 10.4 compared to 67 questions asked during EIST'16 as seen in Table 10.2. This calculation is based on complete *knowledge item* sets in which students also received an appropriate answer to their question. Still to consider is the growth in student population by 25% from 1142 in EIST'16 to 1432 in EIST'17. However, this cannot account for such an increase in the total number of questions asked. Furthermore, only 6 out of 356 questions were asked anonymously by using the anonymous question feature which allows to hide the username when asking questions. This highlights that semi-anonymity paired with not being exposed to the whole student audience seems to be sufficient for many students to break interaction barriers. For the use of *Slack* and AMATI, students needed to sign up with their university identifier but were allowed to choose a username themselves. This allowed us to match our collected data to exam grades while giving students the freedom to choose their own user names instead of using their real names when phrasing questions.

Question Type		# Questions
General	No Context provided	127
Content	Context provided	166
	No Context provided	63
Total answered		356
Total including unanswered		791

Table 10.4: Number of Questions asked in EIST‘17 by category

Based on calculations of all questions and answers provided using the AMATI system we found that for the EIST course during the summer semester 2017 there was an average answer time to questions without teaching context of 520 minutes while questions with teaching context by AMATI took 217 minutes on average to be answered. This is a reduction in time of 58.28% during the summer semester 2017 as described in Section 10.5. The average answer time has been calculated for all questions phrased during and after lecture hours resulting in an expected around the clock availability of moderators.

Context provisioning using AMATI	Average answer time
Context provided by AMATI	217 minutes
No Context provided by AMATI	520 minutes

Table 10.5: Context-provisioning - time to answer in minutes - EIST 2017

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During the EIST course in the summer semester 2018, no additional questionnaire was conducted. The focus of this iteration of our research approach was in the adaptation and development of new features regarding our feedback and results collected from the summer term 2016 and 2017.

AMATI data observations

This subsection compares data observations made at the end of the summer term 2018 and compares the results with data retrieved from the summer semester 2016 and 2017. As the student numbers have been grown steadily (25% in 2016 and 13.55% in 2017), also the number of complete *knowledge item* sets also have increased (431.43% in 2017 and 63.30% in 2018) as seen in Table 10.6. Interpreting these results with caution, we can say that AMATI scales for higher student populations under the premise that more tutors or moderators are made available for answering questions. In addition, we can see that student questions phrased and answers provided in form of full *knowledge item* sets are growing with higher percentages than the student population itself, denoting there is still an increased adaption to the AMATI framework.

Course	# Students	Increase %	# Complete *knowledge item* sets	Increase %
EIST 2016	1142	-	67	-
EIST 2017	1431	25.30%	356	431.43%
EIST 2018	1625	13.55%	581	63.30%

Table 10.6: Comparison between Student growth and Question-Answer Set growth during EIST 16/17/18

Looking at the introduction of the new *ModeratorWall* feature in the summer semester 2018, we can see a high adoption by moderators as nearly a third of all student questions have been answered using the *ModeratorWall* compared to *Slack* as seen in Table 10.7. These results are interesting due to the fact that the addition of the *ModeratorWall* feature was under development in the beginning of the summer semester 2018 and was rolled out after 4 weeks of lecturing out of 14 weeks in total.

Answered by	# Of Answers	%
AMATI (ModeratorWall)	192	33.04%
Moderator #1	78	13.42%
Moderator #2	65	11.18%
Moderator #3	20	3.44%
Moderator #4	18	3.09%
Moderator #5	18	3.09%
Moderator #6	17	2,92%
Moderator #7	17	2,92%
Moderators (Other)	156	26.85%
Overall Questions Answered	581	

Table 10.7: Comparison of Answers given by Moderators after the introduction of the *ModeratorWall*

Based on calculations of all questions and answers provided using the AMATI system we found that during the summer semester 2018 there was an average answer time to questions without teaching context of 2847 minutes, while questions which have been provisioned with teaching context by AMATI took 2230 minutes on average to be answered. This is a reduction in time of 21.67% during the summer semester 2017 as described in Table 10.8. The average answer time has been calculated alike the average answer time of the summer semester 2018 assuming an around the clock availability of moderators.

Context provisioning using AMATI	Average answer time
Context provided	2230 minutes
No Context provided	2847 minutes

Table 10.8: Context-provisioning - time to answer in minutes - EIST 2018

10.2 Quantitative Analysis

A quantitative analysis was conducted after the EIST course in the summer term 2017. The following subsection describes the approach on how this analysis was conducted and which statistical measures were used.

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For the EIST course of the year 2017 we were able to collect student exam results in combination with all student questions phrased using the AMATI framework during the semester. We compared the collected examination results with our AMATI usage data as follows:
First, the number of questions asked by each student was mapped to the number of points scored in the final exam. To have consistent data the students registered for the exam who chose not to attend the exam were removed from the data set as their score of zero points is not representative of their knowledge state. Furthermore, students who failed the exam intentionally to retry at a later point in their study were excluded as well. This was done by removing all entries with an exam score of less than 20 points. The 20 point threshold was determined by manually examining the data set and exams. The points scored in the final exam were chosen as the dependent variable and were coded as a scale variable ranging from 0 to 90 points. The number of questions asked were mapped to the independent variable. To perform a one-way analysis of variance test (ANOVA) [TFU07] the data was classified into three student groups:

Group 0 - No questions asked via AMATI

Group 1 - A single question asked via AMATI

Group 2 - More than one question asked via AMATI

To ensure validity of the ANOVA result, the data was inspected beforehand. First, the groups were checked for possible outliers. The analysis of the generated box plot and descriptive statistics of the individual groups showed no outliers as seen in Figure 10.2. Second, the groups were checked for homogeneity of variances using the Levene's test provided by IBM SPSS Statistics Software[1]. The Levene's test showed no violation of the homogeneity of variances, therefore a one-way ANOVA was executed.

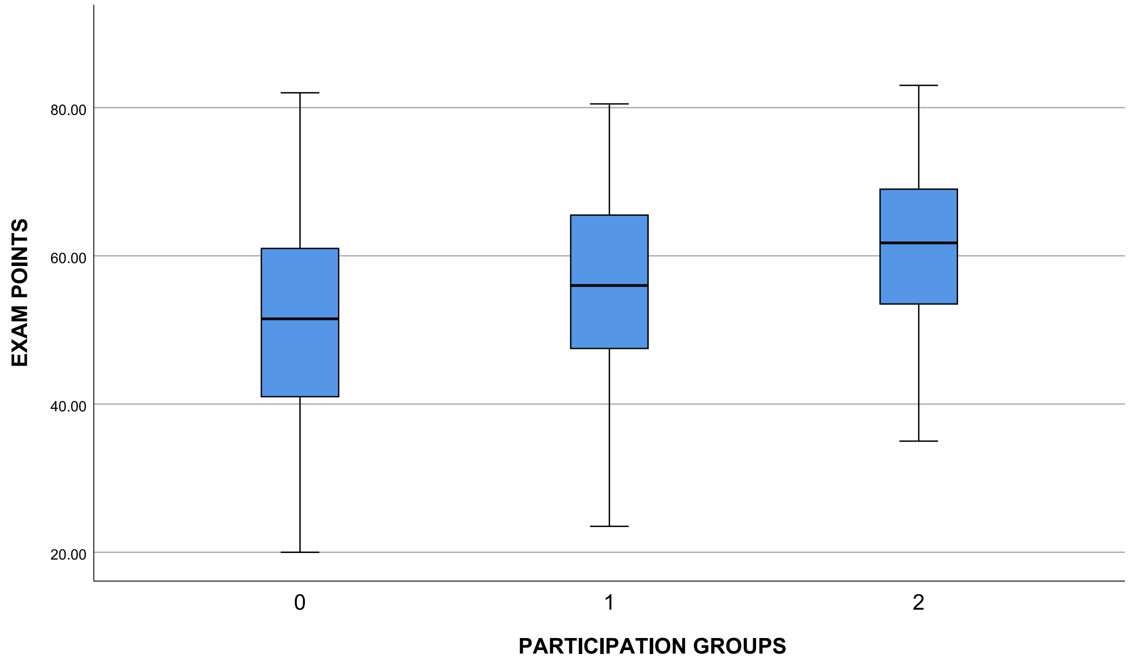

Figure 10.2: EIST 17 student score performance based on communication groups (ANOVA box-plot)

The ANOVA showed a statistically significant difference between the three groups described above ($F(2, 827) = 15.789, p \leq 0.001$). A Tukey post hoc test revealed that students who asked more than one question ($60.750 \pm 11.988, p \leq 0.001$) and students who asked exactly one question ($55.823 \pm 12.462, p = 0.012$) scored significantly higher in the exam than students who asked no questions at all (50.858 ± 13.600). There was no statistically significant difference between the students who asked one question and students who asked two or more questions ($p = 0.125$). The results of the ANOVA including its post hoc Tukey test are shown in the appendix in Table 1 and Table 2. To allow better interpretation of the results the effect size was calculated using the η^2 method shown in Equation 10.1 [LH02].

$$\eta^2 = \frac{SS_{between}}{SS_{total}} \tag{10.1}$$

[1]https://www.ibm.com/de-de/products/spss-statistics

The effect size for the ANOVA resulted in $\eta^2 = 0.037$. Using Cohen's scale [Coh88] this can be interpreted as a small effect of questions asked on the points scored in the final exam.

10.3 Evaluation Summary

The overall results of our descriptive analysis and quantitative analysis are encouraging. When introducing *Slack* in the summer semester 2016, students felt distracted by the use of a chat platform as they needed to divide their attention between the lecture content and phrasing and following questions.
This led to the introduction of context-aware teaching information using AMATI during the summer semester 2017. A reduction of distraction was found by using multiple projectors and the *QuestionWall* feature which allowed students to focus on lecture content during lecture hours. During the summer semester 2017 we also saw an increase of incoming student questions of 431%. Applying quantitative measures by using an ANOVA test in the same year, we were able to show that students that participated in class by providing a minimum of one or more questions scored significantly better in the exam than students that did not participate at all. In addition usage data analysis has shown that teaching context helped moderators to answer questions up to 58.28% faster compared to questions without teaching context.
During the summer semester of 2018 we measured an another increase of 63.30% of *knowledge item* sets. However, this introduced problems regarding the supervision of questions by moderators. Therefore we introduced the *ModeratorWall* to help moderators to find open questions including their context to answer student questions more efficiently. The *ModeratorWall* immediately received a high adoption rate of 33.04%. Questions during the summer semester 2018 where still answered 21.67% faster by moderators when a teaching context was available.
Finally, students saw an increased value (50.00% over 42.04%) in using AMATI compared to just standalone *Slack* as a chat platform.

10.4 Threats to Validity

In this section we discuss threats to validity with regards to our evaluation. We have separated our results in two major categories, *test* validity and *experimental* validity. While *test* validity focuses on the correct creation of experiments in the form of *construct* [CM55] and *content* [Lyn86] validity, *experimental* validity details the *internal* and *external* validity according to Donald Campbell [Cam63] as well as *conclusion* validity based on Thomas Cook [CCS02].

In the following we focus on *construct* validity in combination with internal and external validity.
When *constructing* the case studies, we based the evaluation on two separate inputs to spread information collection to distinct channels allowing better interpretation.
First, we conducted questionnaires with respect to four different categories, *general*, *methodology*, *tool evaluation* and *AMATI specific*, using Likert scales for a standardized result interpretation. This allowed the independent measures of MOCCA as methodology as well as evaluating concrete features of the AMATI framework. Second, usage data was collected from the AMATI framework to analyze concrete usage numbers and statistics. This data set was used in combination with data available from student exam results.
When running the experiments we respected internal validity to our two hypotheses stated in Chapter 1. While the experiment covered 20.8% of the student population, we cannot say with certainty that all the students who participated in the questionnaire have also been the students which used the AMATI framework, as the questionnaire allowed participants not to answer specific questions with respect to AMATI. This may have reduced the expressiveness of some of our questionnaire answers. When analyzing student exam performance related to student participation we used the ANOVA test following up with a post-hoc Tukey test, while filtering our data set by removing outliers. The ANOVA test conducted can therefore be seen as internally valid. By focusing only on *knowledge item* sets as a measurement of participation, other impacting factors for exam results such as lecture involvement [Mur+09], student assessment [Sti94] and participating in homeworks [Coo+98] have not been addressed.
With regards to *external* validity, our results have been collected in a single course over the range of three years at a single university. It is hard to predict the results for lectures in other disciplines or other university environments in other countries, in particular if students do not bring laptops or other smart devices to the classroom.
However, from personal experience by presenting AMATI and MOCCA at conferences and workshops, there is anecdotal evidence that our results are applicable in other environments.

Chapter 11
Conclusion

> I never teach my pupils, I only attempt to provide the conditions in which they can learn.
>
> Albert Einstein

This chapter summarizes the contributions that have been made in this dissertation. It also points out possible future work to be presented in order to further increase student to teacher interaction in direct instruction lectures.

11.1 Contributions

The contributions of this work are three-fold:
First, a new teaching methodology MOCCA was introduced to guide through the transformation process from a traditional MOCC using direct instruction with high a student to instructor ratio to an interactive classroom using AMATI and MOCCA. This has been achieved by introducing *Morning Quizzes* for students to reflect on their existing knowledge, establishing a *dialog* between students and moderators by creating a virtual one-to-one supervision experience and offering a *live feed* of existing questions and answers, while minimizing distraction. *Review breaks* allowed synchronization between question moderators and instructors in order to refine lecture material. A *knowledge base* for students allowes to recapitulate lectures and prepare for the exam. *Supported exercises* allowed students to work on exercises during lecture hours while being assisted by tutors as part of an active learning approach.
Second, a software framework called AMATI was introduced to increase in-class interactions *by more then 400 percent* measuring complete question and answer sets during the EIST course in the summer semester 2016 and 2017. This has been made possible by incorporating *teaching context* into an digital question-answer process during and after lecture hours. To provide this additional context a *chat bot* in conjunction with a *presenter client* was introduced which allows to store all teaching

relevant information from an instructor laptop in combination with student questions and moderator answers in a central *repository*. This process reduced the *time-to-answer* for context-specific questions by up to 58% compared with questions without any context on the teaching material. In addition, instructors are able to analyse their lecture material based on the number of student questions and feedback using the AMATI *dashboard*.

Third, a two-fold evaluation was performed starting with a descriptive analysis of AMATI and MOCCA during the courses of EIST in the summer semester 2016 and the summer semester 2017. The results show that AMATI and its included teaching context has proven to be more recommendable by students than using a chat platform like *Slack* as a standalone approach with regards to distraction, breaking barriers of interaction, receiving answers in a timely manner and absorbing lecture content when phrasing questions using AMATI. In addition, the use of AMATI has shown that the AMATI framework is still increasing its adaptation, as the number of questions phrased is growing significantly faster (431.43% from 2016 to 2017 and 63.13% from 2017 to 2018) than the student population (25.30% from 2016 to 2017 and 13.55% from 2017 to 2018) which used the AMATI framework during the EIST course over the three semesters.

The descriptive analysis was followed up by a quantitative evaluation of AMATI in a pool of 1431 software engineering students, using the EIST 2017 course. The results show, that actively participating students who asked more than one question ($60.750 \pm 11.988, p \leq 0.001$) and students who asked exactly one question ($55.823 \pm 12.462, p = 0.012$) scored significantly higher in the final exam than students who asked no questions at all (50.858 ± 13.600).

Finally, considering the two hypothesis stated in the beginning of this work, we are able to say we were able to increase student participation by introducing digital means of communication (HP1). Further we have shown that increased interaction during lecture hours can have a positive impact on student grade performance (HP2).

11.2 Future Work

MOCCA and AMATI have increased the number of student questions asked significantly from 2016 to 2018. This also led to a strong increase of manually provided answers given by moderators. To deal with this increasing demand, the communication load on the moderator needs to be redesigned. Svilen Stefanov [Ste18] analyzed the existing knowledge base and elaborated new means to automatically suggest answers based on existing question and answer pairs. Using natural language processing and machine learning the load of moderators could be decreased even more by offering such a service

in the future. In addition, Frank Hermann developed a method for the aggregation of teaching context by enforcing students to select an appropriate teaching context manually before asking questions. This comes with the benefit of completely removing a chat platform and attaching discussions directly to the teaching context. In addition, a note feature allows students to take notes on particular slides as well as allowing students to mark their learning process using existing slide sets [Her18].
Johannes Flemke investigated the technical feasibility of semi-automated lecture slide customization based on morning quiz results of the student population. This allows instructors to tailor Massive On Campus Courses based on students needs [Fle15].

Bibliography

[Ada13] P. Adamopoulos. “What makes a great MOOC? An interdisciplinary analysis of student retention in online courses.” In: *International Conference on Information Systems (ICIS 2013): Reshaping Society Through Information Systems Design* 5 (January 2013).

[Afr14] R. Afreen. “Bring your own device (BYOD) in higher education: opportunities and challenges.” In: *International Journal of Emerging Trends & Technology in Computer Science* (March 2014).

[AL97] J. D. Angrist and V. Lavy. *Using Maimonides' rule to estimate the effect of class size on student achievement.* Tech. rep. National Bureau of Economic Research, 1997.

[And+03] R. J. Anderson, R. Anderson, T. VanDeGrift, S. Wolfman, and K. Yasuhara. “Promoting interaction in large classes with computer-mediated feedback.” In: *Designing for change in networked learning environments.* Springer, 2003.

[Ari0 a] Aristotle. *Metaphysics.* 350 BC.

[Ari0 b] Aristotle. *Nicomachean Ethics - Book 2.* 350 BC.

[Bas79] B. Bass. *Organizational Psychology.* Allyn and Bacon, 1979. ISBN: 9780205060108.

[BD09] B. Bruegge and A. H. Dutoit. *Object-Oriented Software Engineering: Using UML, Patterns and Java.* 3rd ed. Prentice Hall, 2009. ISBN: 1292024011.

[BE91] C. C. Bonwell and J. A. Eison. *Active Learning: Creating Excitement in the Classroom. 1991 ASHE-ERIC Higher Education Reports.* ERIC, 1991.

[Beg64] D. Beggs. *Team teaching: bold new venture.* Indiana University Press, 1964.

[Ben15] J. Bentham. *Chrestomathia: Being a Collection of Papers, Explanatory of the Design of an Institution, Proposed to be Set on Foot, Under the Name of the Chrestomathic Day School*. Messrs. Payne, Foss, and R. Hunter, 1815.

[BG06] C. J. Bonk and C. R. Graham. *The handbook of blended learning: Global perspectives, local designs*. Pfeiffer, 2006. ISBN: 9780787977580.

[Big11] J. B. Biggs. *Teaching for quality learning at university: What the student does*. McGraw-Hill Education (UK), 2011.

[Big96] J. Biggs. "Enhancing teaching through constructive alignment." In: *Higher Education* 32.3 (1996).

[Bla+02] P. Blatchford, V. Moriarty, S. Edmonds, and C. Martin. "Relationships between Class Size and Teaching: A Multimethod Analysis of English Infant Schools." In: *American Educational Research Journal* 39.1 (2002), pp. 101–132.

[Blo56] B. Bloom. *Taxonomy of Educational Objectives: The Classification of Educational Goals*. Taxonomy of Educational Objectives: The Classification of Educational Goals Bd. 1. D. McKay, 1956.

[BPS01] A. Butler, K.-B. Phillmann, and L. Smart. "Active learning within a lecture: Assessing the impact of short, in-class writing exercises." In: *Teaching of Psychology* 28.4 (2001).

[Bru98] K. A. Bruffee. *Collaborative learning: Higher education, interdependence, and the authority of knowledge.* 2. The Johns Hopkins University Press, 1998. ISBN: 9780801859748.

[BS12] J. Bergmann and A. Sams. *Flip your classroom: Reach every student in every class every day.* International society for technology in education, 2012.

[BS89] L. J. Bannon and K. Schmidt. "CSCW: Four characters in search of a context." In: *ECSCW 1989: Proceedings of the First European Conference on Computer Supported Cooperative Work*. Computer Sciences Company, London. 1989.

[Buc99] F. Buckley. *Team Teaching: What, Why, and How?* SAGE Publications, 1999. ISBN: 9781452221519.

[BWD14] P. Baepler, J. Walker, and M. Driessen. *It's not about seat time: Blending, flipping, and efficiency in active learning classrooms*. 2014.

[Cal07] J. E. Caldwell. "Clickers in the large classroom: Current research and best-practice tips." In: *CBE-Life sciences education* 6.1 (2007).

[Cam63] D. T. Campbell. "Experimental and quasi-experimental designs for research on teaching." In: *Handbook of research on teaching* 5 (1963).

[CCS02] T. D. Cook, D. T. Campbell, and W. Shadish. *Experimental and quasi-experimental designs for generalized causal inference*. Houghton Mifflin Boston, MA, 2002. ISBN: 9780395615560.

[Cho02a] N. Chomsky. *On Nature and Language*. Ed. by A. Belletti and L. Rizzi. Cambridge University Press, 2002.

[Cho02b] N. Chomsky. *Syntactic Structures*. 2nd ed. Mouton and Co., 2002. ISBN: 3110172798.

[CM55] L. J. Cronbach and P. E. Meehl. "Construct validity in psychological tests." In: *Psychological bulletin* 52.4 (1955).

[Coh88] J. Cohen. "Statistical power analysis for the behavioral sciences . Hilsdale." In: *NJ: Lawrence Earlbaum Associates* 2 (1988).

[Coo+98] H. Cooper, J. J. Lindsay, B. Nye, and S. Greathouse. "Relationships among attitudes about homework, amount of homework assigned and completed, and student achievement." In: *Journal of educational psychology* 90.1 (1998).

[Cro01] T. Crooks. "The validity of formative assessments." In: *British Educational Research Association Annual Conference, University of Leeds*. 2001, pp. 13–15.

[Dal70] E. Dale. *Audiovisual methods in teaching*. 3. Holt,Rinehart & Winston of Canada Ltd, 1970. ISBN: 0039100545.

[Dav66] H. S. Davis. *How to Organize an Effective Team Teaching Program. Successful School Management Series.* Prentice-Hall, 1966.

[Dav95] J. R. Davis. *Interdisciplinary courses and team teaching: New Arrangements for Learning*. Greenwood Press, 1995. ISBN: 0897748875.

[Del19] T. Delft. *Feedbackfruits*. August 2019. URL: `https://feedbackfruits.com/`.

[Dij82] E. W. Dijkstra. "On the role of scientific thought." In: *Selected writings on computing: a personal perspective*. Springer, 1982.

[Ehr+01] R. G. Ehrenberg, D. J. Brewer, A. Gamoran, and J. D. Willms. "Class size and student achievement." In: *Psychological Science in the Public Interest* 2.1 (2001).

[Eng80] S. Engelmann. *Direct instruction*. Vol. 22. Educational Technology, 1980.

[Eng+88] S. Engelmann, W. C. Becker, D. Carnine, and R. Gersten. "The direct instruction follow through model: Design and outcomes." In: *Education and Treatment of Children* (1988).

[FB03] R. M. Felder and R. Brent. "Learning by doing." In: *Chemical engineering education* 37.4 (2003).

[Fel11] P. Felicia. *Handbook of Research on Improving Learning and Motivation through Educational Games: Multidisciplinary Approaches: Multidisciplinary Approaches*. IGI Global, 2011. ISBN: 1609604954.

[Fle15] J. Flemke. "Handling of lecture content for heterogenous state of knowledge of the audience." Master Thesis. Faculty of Informatics, Technical University of Munich, 2015.

[Fre+14] S. Freeman, S. L. Eddy, M. McDonough, M. K. Smith, N. Okoroafor, H. Jordt, and M. P. Wenderoth. "Active learning increases student performance in science, engineering, and mathematics." In: *Proceedings of the National Academy of Sciences* 111.23 (2014).

[FS+88] R. M. Felder, L. K. Silverman, et al. "Learning and teaching styles in engineering education." In: *Engineering education* 78.7 (1988).

[Gam95] E. Gamma. *Design patterns: elements of reusable object-oriented software*. Pearson Education, 1995.

[Gar83] H. Gardner. *Frames of Mind: The Theory of Multiple Intelligences*. Basic Books, 1983. ISBN: 9780465025084.

[Ger17] F. S. O. Germany. *Federal Statistics Office Germany: First-year students: Germany, semester, nationality, sex*. August 2017. URL: `https://www-genesis.destatis.de/genesis/online/logon?sequenz=tabelleErgebnis&selectionname=21311-0010`.

[Gig16] E. Gigantiello. "A Live Feedback Tool to support Blended Learning Methodologies in Multi-Classroom Teaching Environments." Master Thesis. Faculty of Informatics, Technical University of Munich, 2016.

[GK04] D. R. Garrison and H. Kanuka. "Blended learning: Uncovering its transformative potential in higher education." In: *The internet and higher education* 7.2 (2004).

[Gla77] R. Glaser. *Adaptive education: Individual diversity and learning*. Holt, Rinehart and Winston New York, 1977. ISBN: 0030152917.

[Gru94] J. Grudin. "Computer-Supported Cooperative Work: History and Focus." In: *Computer* 27.5 (May 1994).

[Her18] F. Hermann. "OTC - An Online Teaching Client for MOOCs and MOCCs." Master Thesis. Faculty of Informatics, Technical University of Munich, 2018.

[HL04] O. Hazzan and T. Lapidot. "The practicum in computer science education: bridging gaps between theoretical knowledge and actual performance." In: *ACM SIGCSE Bulletin* 36.4 (2004).

[HLW15] G.-J. Hwang, C.-L. Lai, and S.-Y. Wang. "Seamless flipped learning: a mobile technology-enhanced flipped classroom with effective learning strategies." In: *Journal of Computers in Education* 2.4 (2015).

[HOV09] F. Hanusch, L. Obijiofor, and Z. Volcic. "Theoretical and Practical Issues in Team-Teaching a Large Undergraduate Class." In: *International Journal of Teaching and Learning in Higher Education* 21.1 (2009).

[Hox00] C. M. Hoxby. "The effects of class size on student achievement: New evidence from population variation." In: *The Quarterly Journal of Economics* 115.4 (2000).

[HS13] C. F. Herreid and N. A. Schiller. "Case studies and the flipped classroom." In: *Journal of College Science Teaching* 42.5 (2013).

[Hym74] R. T. Hyman. *Ways of teaching*. Lippincott Williams & Wilkins, 1974.

[Inc17] S. Inc. *Slack: Be less busy*. April 2017. URL: `https://slack.com/`.

[Jac93] I. Jacobson. *Object-oriented software engineering: a use case driven approach*. Pearson Education India, 1993.

[JJ08] R. T. Johnson and D. W. Johnson. "Active learning: Cooperation in the classroom." In: *The annual report of educational psychology in Japan* 47 (2008).

[Joh88] R. Johansen. *GroupWare: Computer Support for Business Teams*. New York, NY, USA: The Free Press, 1988. ISBN: 0029164915.

[KB05] J. Kornmeier and M. Bach. "The Necker cube—an ambiguous figure disambiguated in early visual processing." In: *Vision research* 45.8 (2005).

[KD96] A. N. Kluger and A. DeNisi. "The effects of feedback interventions on performance: a historical review, a meta-analysis, and a preliminary feedback intervention theory." In: *Psychological bulletin* 119.2 (1996).

[KG17] J. Knobloch and E. Gigantiello. “AMATI: Another Massive Audience Teaching Instrument.” In: SEUH ’17. CEUR-WS, 2017. URL: `http://ceur-ws.org/Vol-1790/paper07.pdf`.

[KKB18] J. Knobloch, J. Kaltenbach, and B. Bruegge. “Increasing Student Engagement in Higher Education Using a Context-aware Q&A Teaching Framework.” In: *Proceedings of the 40th International Conference on Software Engineering: Software Engineering Education and Training.* ICSE-SEET ’18. Gothenburg, Sweden: ACM, 2018. ISBN: 978-1-4503-5660-2.

[KL09] R. H. Kay and A. LeSage. “Examining the benefits and challenges of using audience response systems: A review of the literature.” In: *Computers & Education* 53.3 (2009).

[Kof14] K. Koffka. *Principles of Gestalt psychology.* Mimesis International, 2014. ISBN: 8857523934.

[Köh67] W. Köhler. “Gestalt psychology.” In: *Psychological research* 31.1 (1967).

[Kol14] D. A. Kolb. *Experiential learning: Experience as the source of learning and development.* 2. Pearson Education (US), 2014. ISBN: 0133892409.

[KRM74] D. Kolb, I. Rubin, and J. McIntyre. *Organizational psychology: a book of readings.* Behavioral sciences in business series. Prentice-Hall, 1974.

[Kru+17] S. Krusche, B. Bruegge, I. Camilleri, K. Krinkin, A. Seitz, and C. Wöbker. “Chaordic learning: a case study.” In: *2017 IEEE/ACM 39th International Conference on Software Engineering: Software Engineering Education and Training Track (ICSE-SEET).* IEEE. 2017.

[KS18] S. Krusche and A. Seitz. “ArTEMiS: An automatic assessment management system for interactive learning.” In: *Proceedings of the 49th ACM Technical Symposium on Computer Science Education.* ACM. 2018.

[LH02] T. R. Levine and C. R. Hullett. “Eta Squared, Partial Eta Squared, and Misreporting of Effect Size in Communication Research.” In: *Human Communication Research* 28.4 (2002).

[Liv17] Livestream.com. *Livestream - Broadcast and Watch HD Live Streaming Video Events.* August 2017. URL: `http://livestream.com/`.

[LM07] P. Lynch and S. McCall. “The role of itinerant teachers.” In: *Community Eye Health* 20.62 (2007).

[Loc00] J. Locke. *An Essay Concerning Humane Understanding: In Four Books.* Awnsham, John Churchil..., and Samuel Manship, 1700.

[Lut+18] S. Luttenberger, D. Macher, V. Maidl, C. Rominger, N. Aydin, and M. Paechter. “Different patterns of university students’ integration of lecture podcasts, learning materials, and lecture attendance in a psychology course.” In: *Education and Information Technologies* 23.1 (2018).

[Lyn86] M. R. Lynn. “Determination and quantification of content validity.” In: *Nursing research* (1986).

[Mar12] F. G. Martin. “Will Massive Open Online Courses Change How We Teach?” In: *Commun. ACM* 55.8 (August 2012). ISSN: 0001-0782.

[McP16] J. E. McPeck. *Teaching critical thinking: Dialogue and dialectic*. Vol. 13. Routledge, 2016. ISBN: 1138695610.

[Med14] N. I. o. H. US National Library of Medicine. *OnlineTED.com - a novel web-based audience response system*. August 2014. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3935166/.

[Met17] Metabase. *Metabase*. October 2017. URL: https://metabase.com/.

[MH97] E. Mazur and R. C. Hilborn. *Peer instruction: A user’s manual*. Vol. 5. Prentice Hall Upper Saddle River, NJ, 1997.

[Moo17] Moodle. *Moodle - Open-source learning platform | Moodle.org*. August 2017. URL: https://moodle.org/.

[Mor19] E. Morse. *J. Pillans, James*. Oxford Dictionary of National Biography (online ed.) Oxford University Press, 2019.

[Mos95] F. Mosteller. “The Tennessee study of class size in the early school grades.” In: *The future of children* (1995).

[MS15] F. K. und M. Schuhen. *Feedback zum Lernfortschritt der Studierenden während der Vorlesung*. August 2015. URL: https://www.zfhe.at/index.php/zfhe/article/download/812/661.

[Mur+09] P. K. Murphy, I. A. Wilkinson, A. O. Soter, M. N. Hennessey, and J. F. Alexander. “Examining the effects of classroom discussion on students’ comprehension of text: A meta-analysis.” In: *Journal of educational psychology* 101.3 (2009).

[MW97] B. L. McCombs and J. S. Whisler. *The Learner-Centered Classroom and School: Strategies for Increasing Student Motivation and Achievement*. John Wiley & Sons, 1997. ISBN: 0787908363.

[Nei14] U. Neisser. *Cognitive psychology: Classic edition*. Psychology Press, 2014.

[Onl17] OnlineTED. *OnlineTED - Voting made simple*. August 2017. URL: https://www.onlineted.de/.

[Pav27] I. P. Pavlov. *Conditional reflexes: an investigation of the physiological activity of the cerebral cortex.* Oxford Univ. Press, 1927.

[PC52] J. Piaget and M. Cook. *The origins of intelligence in children.* Vol. 8. 5. International Universities Press New York, 1952.

[Pet+96] A. Petersen et al. *Dictionary of Islamic architecture.* Psychology Press, 1996. ISBN: 0415213320.

[Pla0 a] Plato. *The Republic.* 360 BC.

[Pla0 b] Plato. *The Republic BOOK VI.* 360 BC.

[Pop05] K. Popper. *The logic of scientific discovery.* Routledge, 2005.

[Pop72] K. R. Popper. *Objective knowledge.* Vol. 360. Oxford University Press Oxford, 1972.

[Ree79] T. Reenskaug. *Model-View-Controller - Origins.* 1979. URL: `http://heim.ifi.uio.no/~trygver/themes/mvc/mvc-index.html`.

[Rev11] R. Revans. *ABC of action learning.* Routledge, 2011. ISBN: 140942703X.

[RRV19] J. Reich and J. A. Ruipérez-Valiente. “The MOOC pivot.” In: *Science* 363 (January 2019), pp. 130–131. DOI: `10.1126/science.aav7958`.

[RSJ96] R. E. Reynolds, G. M. Sinatra, and T. L. Jetton. “Views of knowledge acquisition and representation: A continuum from experience centered to mind..” In: *Educational Psychologist* 31.2 (1996).

[SAW94] B. Schilit, N. Adams, and R. Want. “Context-aware computing applications.” In: *Mobile Computing Systems and Applications, 1994. WMCSA 1994. First Workshop on.* IEEE. 1994, pp. 85–90.

[Sch07] A. Schreyögg. “Fehlerkultur, Fehlermanagement und ihre Bedeutung für Maßnahmen der Personalentwicklung in Kliniken.” In: *Organisationsberatung, Supervision, Coaching* 14.3 (2007).

[Sen06] P. Senge. *The Fifth Discipline: The Art and Practice of the Learning Organization.* Business Management. Random House Business Books, 2006.

[Ski15] B. F. Skinner. *Cumulative record: Definitive edition.* Vol. 4. BF Skinner Foundation, 2015.

[Ski53] B. F. Skinner. *Science and human behavior.* Simon and Schuster, 1953.

[Ski90] B. F. Skinner. *The behavior of organisms: An experimental analysis.* BF Skinner Foundation, 1990.

[Sla17] Slack. *Real Time Messaging API*. October 2017. URL: https://api.slack.com/rtm.

[Sli19] Slido. *Slido - Audience Interaction Made Simple*. August 2019. URL: https://www.sli.do/.

[Sma19] Smartbear.com. *The best APIs are build with Swagger*. May 2019. URL: https://swagger.io/.

[Smi+09] M. K. Smith, W. B. Wood, W. K. Adams, C. Wieman, J. K. Knight, N. Guild, and T. T. Su. "Why peer discussion improves student performance on in-class concept questions." In: *Science* 323.5910 (2009).

[Ste18] S. Stefanov. "BusyBee: A similarity-based Q&A system." Bachelor Thesis. Faculty of Informatics, Technical University of Munich, 2018.

[Sti94] R. J. Stiggins. *Student-centered classroom assessment*. Merrill New York, 1994.

[TFU07] B. G. Tabachnick, L. S. Fidell, and J. B. Ullman. *Using multivariate statistics*. Vol. 5. Pearson Boston, MA, 2007.

[Tho98] E. L. Thorndike. "Animal intelligence: An experimental study of the associative processes in animals." In: *The Psychological Review: Monograph Supplements* 2.4 (1898).

[TMBM18] C. Turro, J. Morales, and J. Busquets-Mataix. "A study on assessment results in a large scale Flipped Teaching Experience." In: Fourth International Conference on Higher Education Advances, June 2018.

[Uni16] H. University. *peripathtiko/s*. October 2016. URL: http://archimedes.fas.harvard.edu/cgi-bin/dict?name=lsj&lang=el&word=peripathtiko%2fs&filter=GreekXlit.

[VGC13] J. Vetterick, M. Garbe, and C. H. Cap. *Tweedback: A Live Feedback System for Large Audiences*. 2013.

[Wat13] J. B. Watson. "Psychology as the behaviorist views it." In: *Psychological review* 20.2 (1913).

[Wer25] M. Wertheimer. *Drei abhandlungen zur Gestalttheorie*. Verlag der Philosophischen Akademie, 1925.

[WK07] K. Wilson and J. H. Korn. "Attention during lectures: Beyond ten minutes." In: *Teaching of Psychology* 34.2 (2007).

[Zyn14] D. Zyngier. "Class size and academic results, with a focus on children from culturally, linguistically and economically disenfranchised communities." In: *Evidence Base* 2014 (April 2014).

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Appendices

1 REST Interface definition

Figure 1 shows all defined CRUD operations available for the AMATI-Repository. They are specified with the following provided color coding.

Green
- CREATE Operations

Blue
- READ Operations

Red
- DELETE Operations

To generate the given API documentation the Swagger framework[Sma19] was used. Swagger generated a API documentation directly from code as well as the client access code for the AMATI-Chatbot component to communicate with the AMATI-Repository.

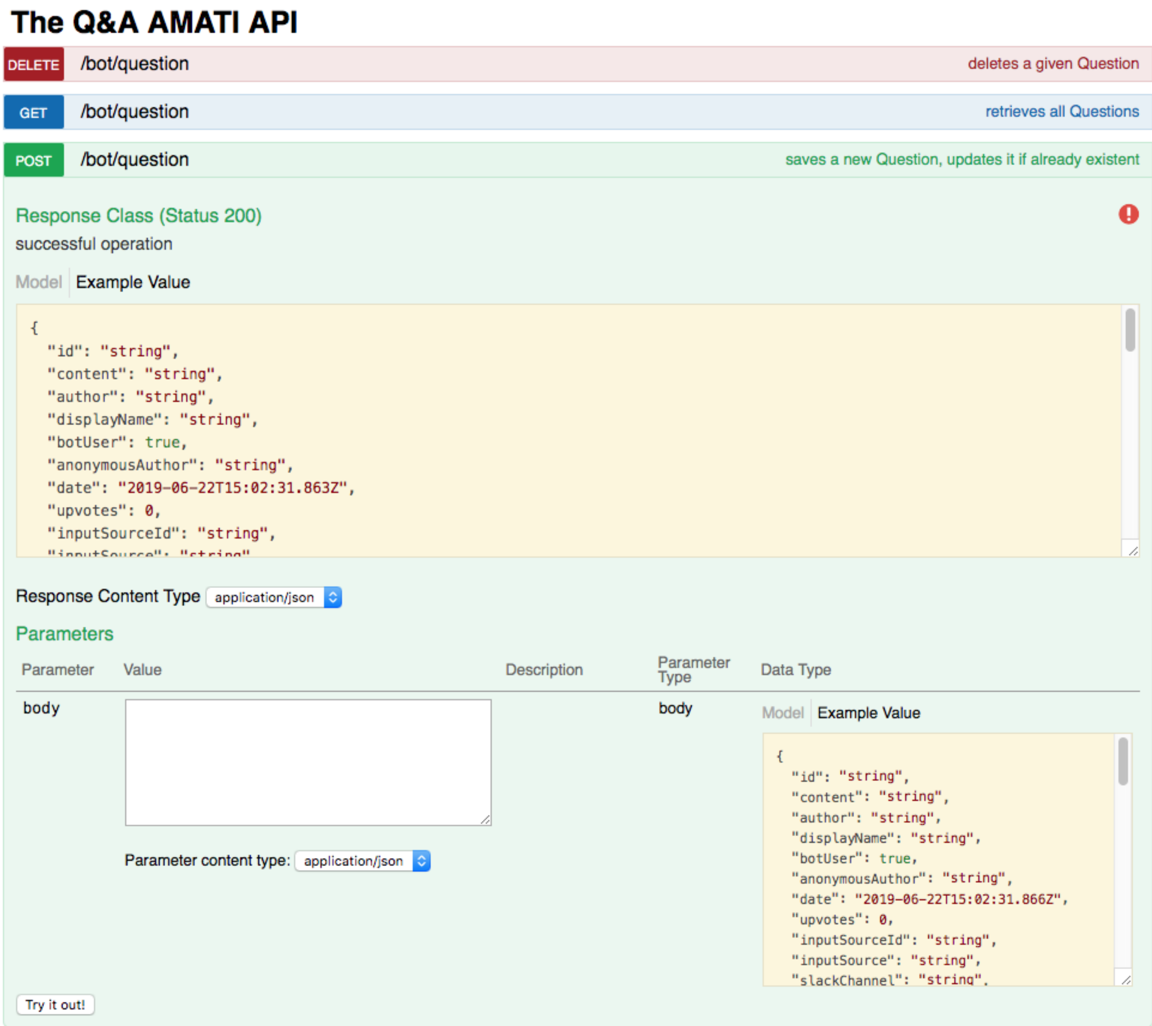

Figure 1: Generated API documentation for the AMATI-Repository using the Swagger framework

2 Object Design Models

Based on the requirements of Chapter 6.1 and the analysis model stated in Chapter 7.2 this section will transform the analysis object model into the concrete implementation of the AMATI framework[1].

The first Subsection 2.1 the detailed design of the *AMATI-Repository*. Subsection 2.2 focuses on the *AMATI-PresenterClient* and Subsection 2.3 describes the *AMATI-ChatBot*. The object design of the *AMATI-Dashboard* is not shown because it completely reuses the *Metabase*[2] framework.

[1] A machine readable version of all the models can be found at this public URL: `https://tinyurl.com/amati-models`

[2] `https://metabase.com/`

2.1 Object Design for AMATI-Repository

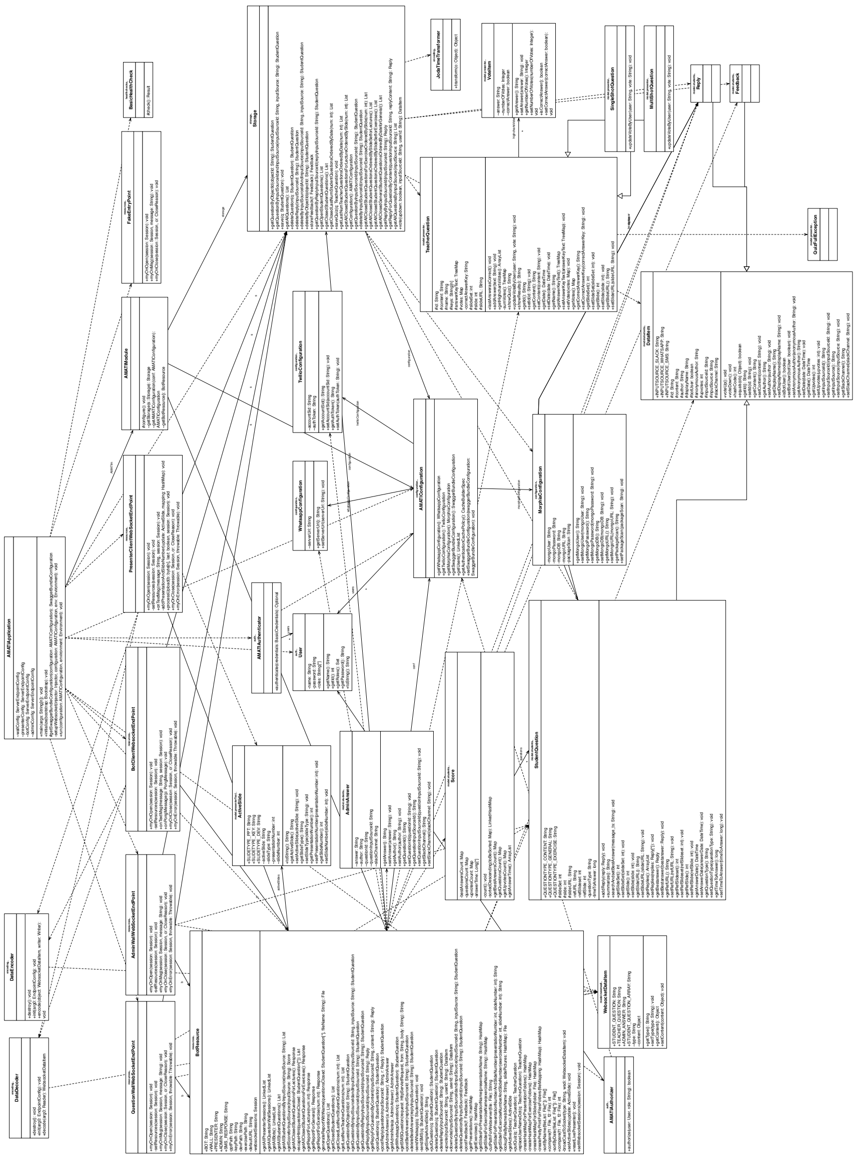

Figure 2: Object model for the AMATI-Repository including internal dependencies (UML class diagram)

2.2 Object Design for AMATI PresenterClient

Figure 3: Object model for the AMATI-PresenterClient including internal dependencies (UML class diagram)

2.3 Object Design for AMATI-Chatbot

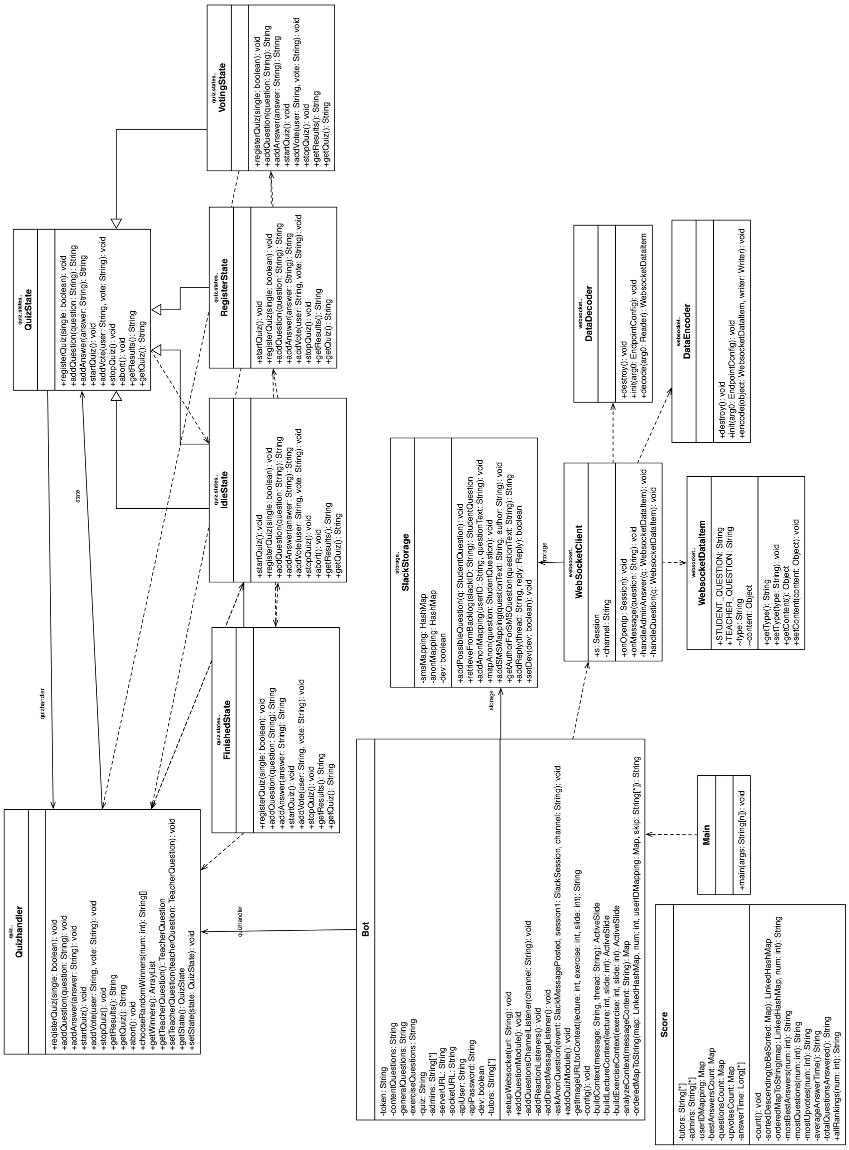

Figure 4: Object model for the AMATI-Chatbot including internal dependencies (UML class diagram)

3 User Interface Design

This section presents some of the GUIs of the AMATI framework which was used during the summer semester 2016, 2017 and 2018.

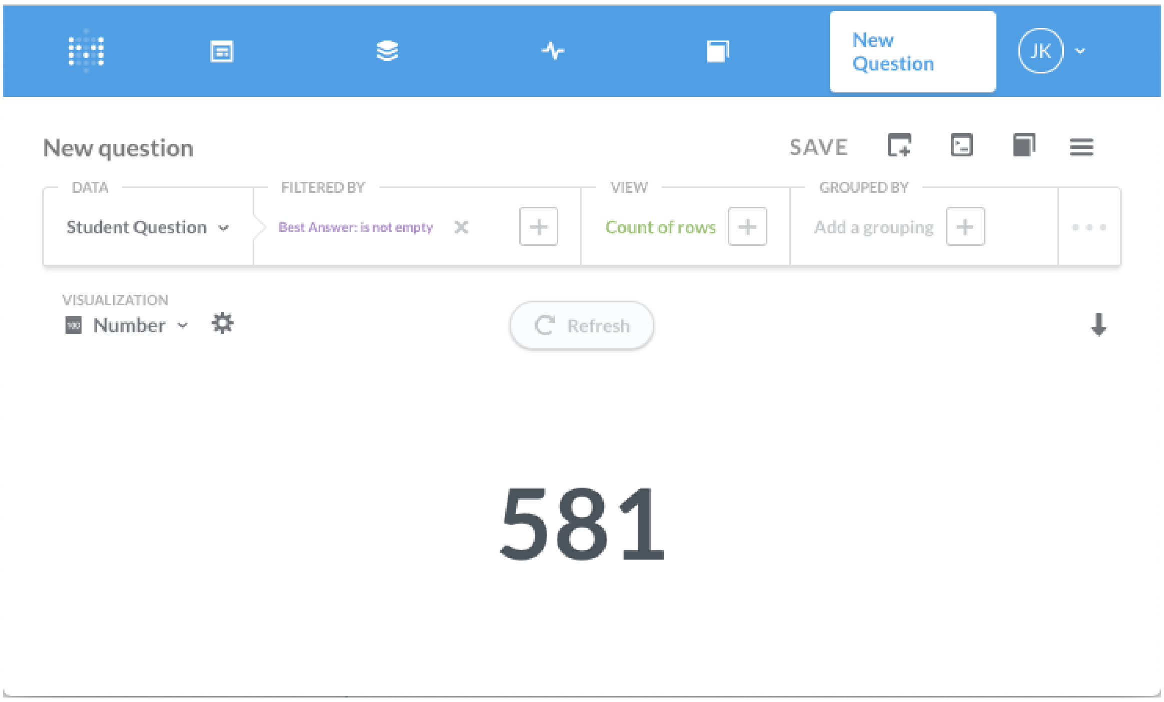

Figure 5: Graphical User Interface of the *AMATI-Dashboard* Query Builder using Metabase. The following query is created: Search all Student Questions which the Best answer is not empty, and count its rows.

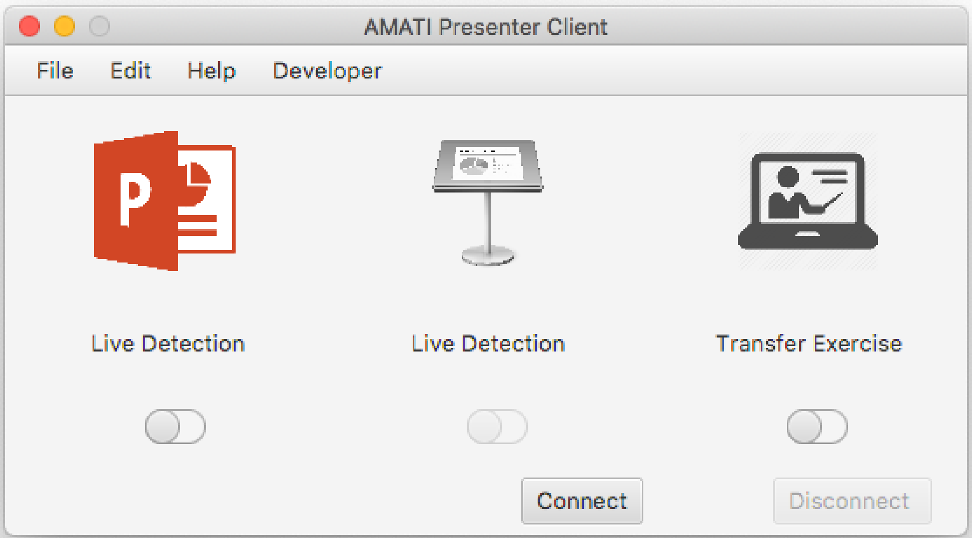

Figure 6: Graphical User Interface of the *AMATI-PresenterClient*, denotes that PowerPoint has been recognized as running application.

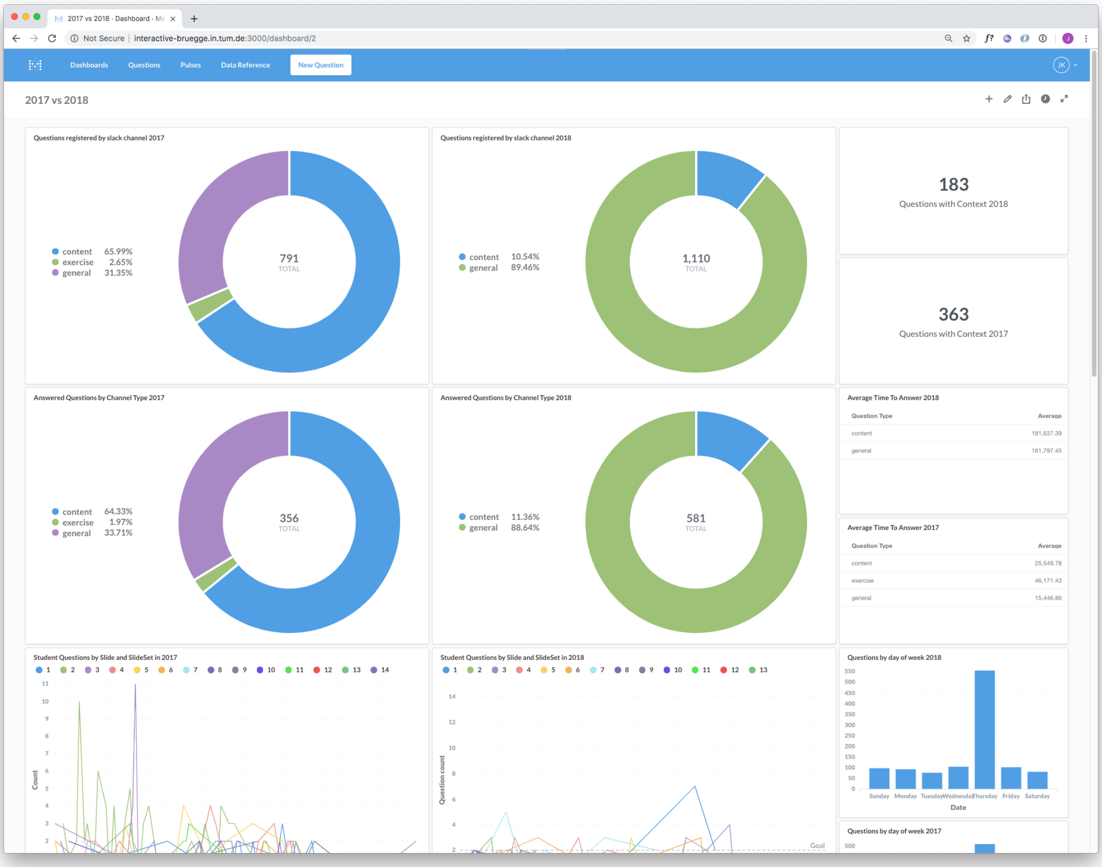

Figure 7: Graphical User Interface of the *AMATI-Dashboard* comparing the EIST summer terms 2017 and 2018. The upper piecharts denote all questions phrased during EIST 2017 (left) and EIST 2018 (right) separated by its categories general, content or exercise question. The lower piecharts contain all answered questions phrased during EIST 2017 (left) and EIST 2018 (right) separated by its categories general, content or exercise question.

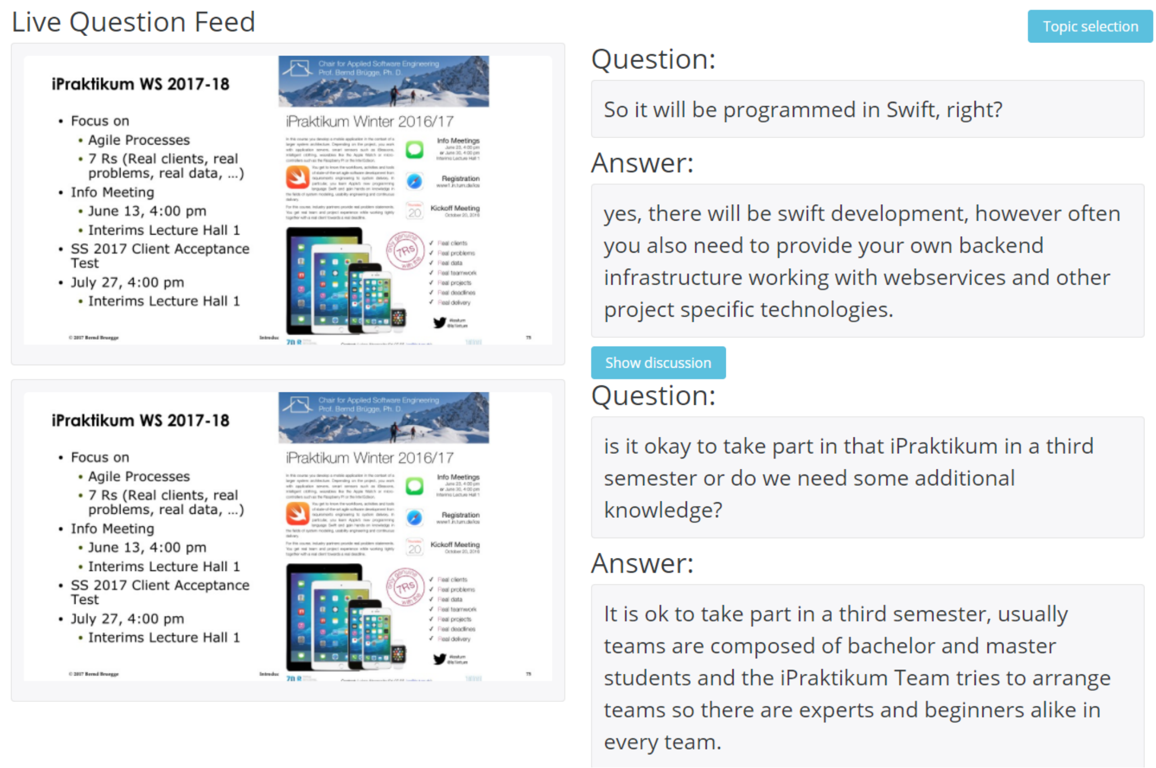

Figure 8: Graphical User Interface of the AMATI-QuestionWall, highlighting two Questions phrased, their respective context and its attached answers provided by a moderator.

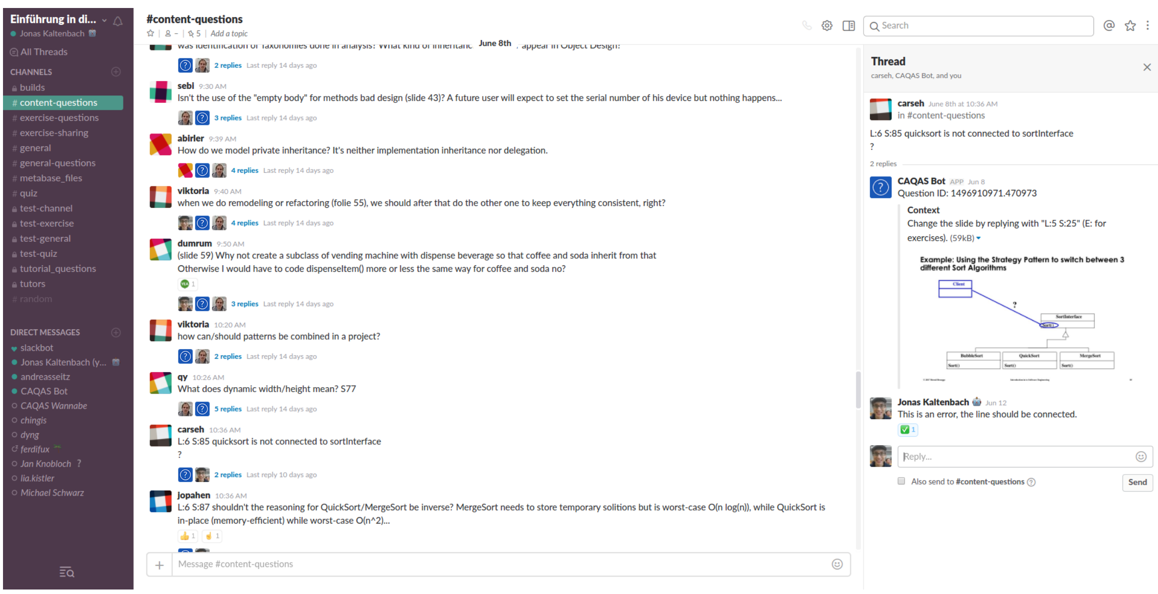

Figure 9: Graphical User Interface of Slack supported by AMATI, highlighting the chat conversion in form of questions in the middle area, a question thread on the right, containing the question, its context, as well as a verified moderator answer.

Case Studies

1 Syllabus for Einführung in die Softwaretechnik - Summer Semester 2016/2017/2018

The following three tables show the syllabi used in the EIST course of summer semester 2016, 2017 and 2018.

Lecture Number	Lecture content
Lecture 01	Introduction
Lecture 02	Modeling with UML
Lecture 03	Modeling with UML
Lecture 04	Activity Diagrams and State-charts Part 1
Lecture 05	System Modeling
Lecture 06	System Modeling II
Lecture 07	Requirements Analysis
Lecture 08	SystemDesign I
Lecture 09	SystemDesign II
Lecture 10	Object Design
Lecture 11	Software Design Patterns
Lecture 12	Object Design II Interfaces
Lecture 13	Mapping Software Models To Code
Lecture 14	Software Lifecycle Modeling
Lecture 15	Scrum
Lecture 16	Build and Release Management
Lecture 17	Software Testing I
Lecture 18	Software Testing II
Lecture 19	Project Management
Lecture 20	Software Evolution
Lecture 21	Lecture Repetitorium

Table 1: Syllabus for the EIST Lecture in the summer semester 2016

Lecture Number	Lecture content
Lecture 01	Introduction
Lecture 02	Modeling with UML
Lecture 03	Modeling with UML
Lecture 04	Requirements Elicitation and Analysis
Lecture 05	System Design I
Lecture 06	System Design II
Lecture 07	Object Design I
Lecture 08	Object Design II
Lecture 09	Pattern-oriented Analysis and Design
Lecture 10	Software Design Patterns
Lecture 11	Mapping Software Models To Code
Lecture 12	Software Lifecycle Modeling
Lecture 13	Software Configuration Management
Lecture 14	Build and Release Management
Lecture 15	Software Testing I
Lecture 16	Software Testing II
Lecture 17	Project Management
Lecture 18	Lecture Repetitorium

Table 2: Syllabus for the EIST Lecture in the summer semester 2017

Lecture Number	Lecture content
Lecture 01	Introduction
Lecture 02	Model-Based Software Engineering - An Introduction
Lecture 03	Requirements Elicitation and Analysis
Lecture 04	System Design I
Lecture 05	System Design II
Lecture 06	Object Design I
Lecture 07	Object Design II
Lecture 08	Model Transformations and Refactorings
Lecture 09	Pattern-oriented Analysis and Design
Lecture 10	Lifecycle Modeling
Lecture 11	Software Configuration Management
Lecture 12	Testing I
Lecture 13	Testing II
Lecture 14	Project Management
Lecture 15	Lecture Repetitorium

Table 3: Syllabus for the EIST Lecture in the summer semester 2018

2 Recording details for Einführung in die Softwaretechnik - Summer Semester 2016/2017/2018

The following tables describe the participation in the live steam and the number of accesses of the lecture recordings during the summer semesters 2016, 2017 and 2018.

#Lecture	# Recording Accesses	# Views of the Livestream	Lecture Time
# 1	3388	0	Thurs. 8:00 AM
# 2	4834	0	Tues. 12:00 PM
# 3	4638	0	Thurs. 8:00 AM
# 4	2502	200	Tues. 12:00 PM
# 5	2164	189	Thurs. 8:00 AM
# 6	1965	100	Tues. 12:00 PM
# 7	1600	94	Tues. 12:00 PM
# 8	2557	145	Thurs. 8:00 AM
# 9	2559	110	Thurs. 8:00 AM
# 10	2387	86	Tues. 12:00 PM
# 11	2523	64	Tues. 12:00 PM
# 12 (part 1 & 2)	2493 & 2185	148 & 121	Thurs. 8:00 AM
# 13	923	65	Tues. 12:00 PM
# 14	1916	173	Thurs. 8:00 AM
# 15	1284	159	Tues. 12:00 PM
# 16	1319	63	Thurs. 8:00 AM
# 17	1221	48	Tues. 12:00 PM
# 18	1412	67	Thurs. 8:00 AM
# 19	1343	50	Tues. 12:00 PM
# 20	1546	60	Thurs. 8:00 AM
# 21	1622	48	Tues. 12:00 PM

Table 4: Number of live stream views and lecture recording downloads of the EIST summer semester 2016 material - Created on: 11th December 2018 based on livestream.com (not archived)

#Lecture	#Views Recording	#Views Livestream	Lecture Time
# 1	1257	not collected	Thurs. 8:00 AM
# 2	342	not collected	Thurs. 8:00 AM
# 3	271	not collected	Thurs. 8:00 AM
# 4	128	not collected	Thurs. 8:00 AM
# 5	62	not collected	Thurs. 8:00 AM
# 6	158	not collected	Thurs. 8:00 AM
# 7	756	not collected	Thurs. 8:00 AM
# 8	116	not collected	Thurs. 8:00 AM
# 9	199	not collected	Thurs. 8:00 AM
# 10	130	not collected	Thurs. 8:00 AM
# 11	39	not collected	Thurs. 8:00 AM
# 12	57	not collected	Thurs. 8:00 AM

Table 5: Number of live stream views and lecture recording downloads of the EIST summer semester 2017 material - Created on: 11th December 2018 based on livestream.com (not archived)

#Lecture	#Views Recording	#Views Livestream	Lecture Time
# 1	41059	301	Thurs. 8:00 AM
# 2	42556	449	Thurs. 8:00 AM
# 3	45540	483	Thurs. 8:00 AM
# 4	67621	517	Thurs. 8:00 AM
# 5	44224	506	Thurs. 8:00 AM
# 6	46163	465	Thurs. 8:00 AM
# 7	34508	454	Thurs. 8:00 AM
# 8	5063	511	Thurs. 8:00 AM
# 9	16530	502	Thurs. 8:00 AM
# 10	12303	440	Thurs. 8:00 AM
# 11	20070	435	Thurs. 8:00 AM
# 12	54926	412	Thurs. 8:00 AM

Table 6: Number of live stream views and lecture recording downloads of the EIST summer semester 2018 material - Created on: 11th December 2018 based on livestream.com (not archived)

Education

1 Teaching models

Section 3.2 lists different teaching models, which are highlighted below:

- Action learning [Rev11]
- Active learning [JJ08]
- Adaptive learning [Gla77]
- Audience Response [KL09]
- Blended Learning [BG06] [GK04]
- Chaordic Learning [Kru+17]
- Collaborative learning [Bru98]
- Experiential learning [Kol14]
- Flipped Classroom[HLW15]
- Kinesthetic learning [FS+88]
- Serious games [Fel11]
- Team learning [Dav95][HOV09]

2 Education Taxonomy

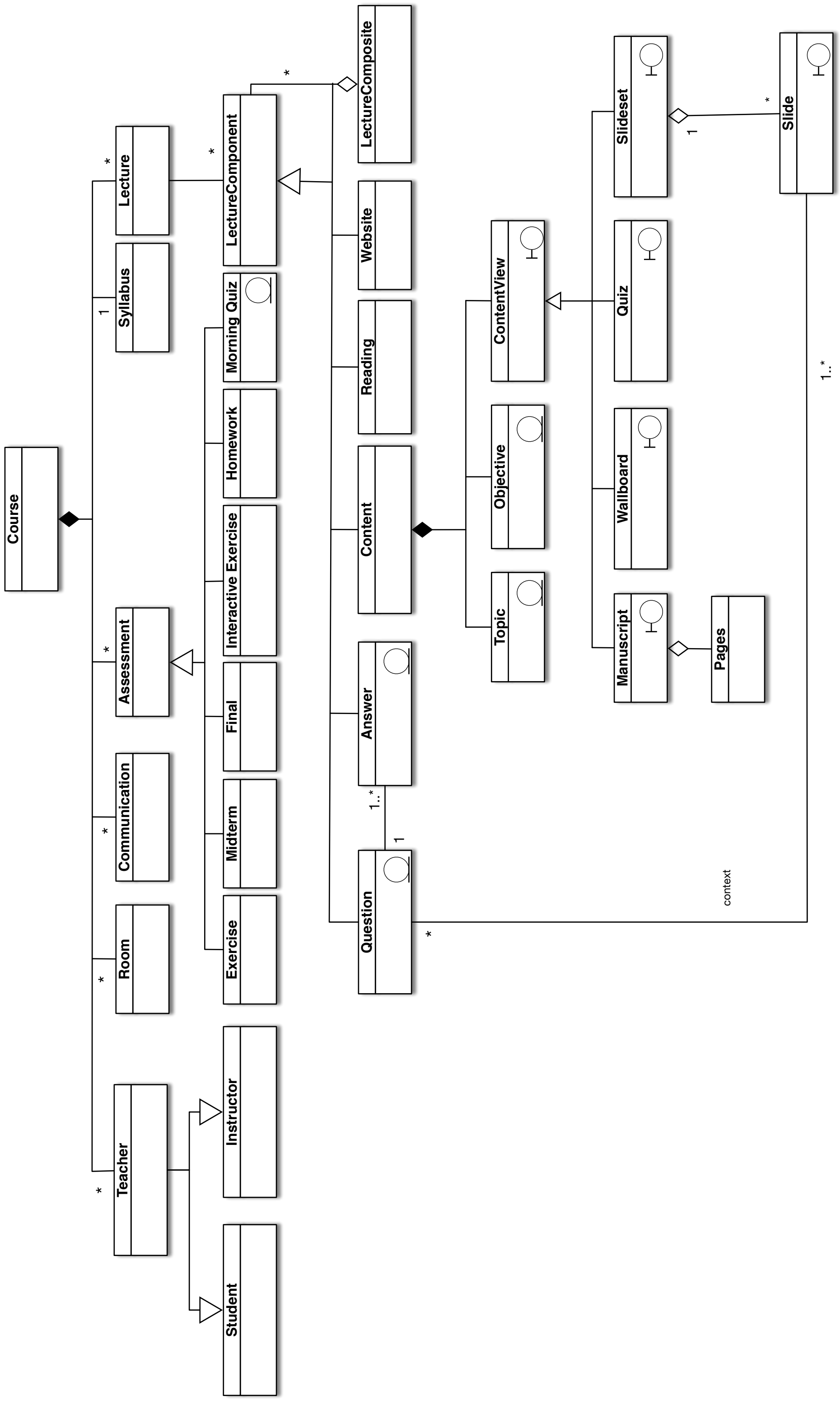

Figure 1: Teaching Taxonomy used in this dissertation (UML class diagram)

Statistics

Below you can find an excerpt of referenced statistics in this thesis [1].

ANOVA
POINTS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5690,739	2	2845,370	15,789	0,000
Within Groups	149034,925	827	180,212		
Total	154725,664	829			

Table 1: Results of the ANOVA test presented in tabular form

Multiple Comparisons
Dependent Variable: POINTS
Tukey HSD

(I) GROUP2		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0	1	-4.96552*	1,73912	0,012	-9,0489	-0,8822
	2	-9.89245*	1,96374	0,000	-14,5032	-5,2817
1	0	4.96552*	1,73912	0,012	0,8822	9,0489
	2	-4,92692	2,52522	0,125	-10,8560	1,0021
2	0	9.89245*	1,96374	0,000	5,2817	14,5032
	1	4,92692	2,52522	0,125	-1,0021	10,8560

*. The mean difference is significant at the 0.05 level.

Table 2: Results of the post hoc Tukey test presented in tabular form

[1] A machine readable version of all the statistical tables can be found at this public URL: `https://tinyurl.com/amati-statistics`

Bevölkerung: Deutschland, Stichtag	
Fortschreibung des Bevölkerungsstandes Deutschland	
Stichtag	Bevölkerungsstand
	Anzahl
31.12.1950	50958125
31.12.1951	51434777
31.12.1952	51863761
31.12.1953	52453806
31.12.1954	52943295
31.12.1955	53517683
31.12.1956	53339626
31.12.1957	54064365
31.12.1958	54719159
31.12.1959	55257088
31.12.1960	55958321
31.12.1961	56589148
31.12.1962	57247246
31.12.1963	57864509
31.12.1964	58587451
31.12.1965	59296591
31.12.1966	59792934
31.12.1967	59948474
31.12.1968	60463033
31.12.1969	61194591
31.12.1970	61001164
31.12.1971	61502503
31.12.1972	61809378
31.12.1973	62101369
31.12.1974	61991475
31.12.1975	61644624
31.12.1976	61441996
31.12.1977	61352745
31.12.1978	61321663
31.12.1979	61439342
31.12.1980	61657945
31.12.1981	61712689
31.12.1982	61546101
31.12.1983	61306669
31.12.1984	61049256
31.12.1985	61020474
31.12.1986	61140461
31.12.1987	61238079
31.12.1988	61715103
31.12.1989	62679035
31.12.1990	79753227
31.12.1991	80274564
31.12.1992	80974632
31.12.1993	81338093
31.12.1994	81538603
31.12.1995	81817499
31.12.1996	82012162
31.12.1997	82057379
31.12.1998	82037011
31.12.1999	82163475
31.12.2000	82259540
31.12.2001	82440309
31.12.2002	82536680
31.12.2003	82531671
31.12.2004	82500849
31.12.2005	82437995
31.12.2006	82314906
31.12.2007	82217837
31.12.2008	82002356
31.12.2009	81802257
31.12.2010	81751602
31.12.2011	80327900
31.12.2012	80523746
31.12.2013	80767463
31.12.2014	81197537
31.12.2015	82175684
31.12.2016	82521653
31.12.2017	82792351

Bis 1989: Früheres Bundesgebiet

Ab 2011: Ergebnisse auf Grundlage des Zensus 2011.

Figure 1: German population through the years 1950 - 2017 based on [Ger17]

Semester	Deutsche			Ausländer			Insgesamt		
	männlich	weiblich	Insgesamt	männlich	weiblich	Insgesamt	männlich	weiblich	Insgesamt
WS 1998/99	102924	94548	197472	15696	17502	33198	118620	112050	230670
WS 1999/00	107213	102210	209423	17661	19234	36895	124874	121444	246318
WS 2000/01	116997	109541	226538	19446	21311	40757	136443	130852	267295
WS 2001/02	127202	118391	245593	22269	24694	46963	149471	143085	292556
WS 2002/03	124201	125852	250053	23879	25717	49596	148080	151569	299649
WS 2003/04	140544	124771	265315	24596	26745	51341	165140	151516	316656
WS 2004/05	131033	120618	251651	23628	25514	49142	154661	146132	300793
WS 2005/06	130815	121184	251999	22823	25017	47840	153638	146201	299839
WS 2006/07	126408	120634	247042	22664	25240	47904	149072	145874	294946
WS 2007/08	134801	130375	265176	22457	25907	48364	157258	156282	313540
WS 2008/09	149455	143495	292950	24845	27830	52675	174300	171325	345625
WS 2009/10	158906	154396	313302	26291	29680	55971	185197	184076	369273
WS 2010/11	166713	159694	326407	28878	31636	60514	195591	191330	386921
WS 2011/12	205921	172735	378656	31785	34879	66664	237706	207614	445320
WS 2012/13	182374	173052	355426	34715	37684	72399	217089	210736	427825
WS 2013/14	184181	177702	361883	37589	39441	77030	221770	217143	438913
WS 2014/15	177377	173150	350527	39712	42041	81753	217089	215191	432280
WS 2015/16	174809	172663	347472	41698	43419	85117	216507	216082	432589
WS 2016/17	173250	174890	348140	43218	44069	87287	216468	218959	435427
WS 2017/18	170784	177137	347921	45216	44600	89816	216000	221737	437737

Figure 2: German first year student population at universities through the years 1998 - 2018 based on [Ger17]

Personalgruppen nach Beschäftigungsverhältnis Geschlecht		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Dozenten und Assistenten	männlich	11284	11014	10945	10753	10799	10227	9690	9630	7152	5769	4349
	weiblich	3559	3431	3566	3609	3803	3550	3595	3763	2722	2299	1808
	Insgesamt	14843	14445	14511	14362	14602	13777	13285	13393	9874	8068	6157
Wissenschaftliche und künstlerische Mitarbeiter	männlich	68443	69317	68951	68663	69095	71315	72068	70232	72432	74627	77672
	weiblich	26937	28225	28877	30015	32429	34709	36250	36184	38911	42003	45873
	Insgesamt	95380	97542	97828	98678	101524	106024	108318	106416	111343	116630	123545
Lehrkräfte für besondere Aufgaben	männlich	3653	3672	3791	3732	3822	3863	3680	3663	3660	3665	3762
	weiblich	2355	2475	2659	2650	2780	2818	2826	2874	2995	3166	3469
	Insgesamt	6008	6147	6450	6382	6602	6681	6506	6537	6655	6831	7231
Sonstiges Personal für Lehre und Forschung	männlich	1	1	1	4	1	-	-	-	-	-	-
	weiblich	43	40	37	33	-	-	-	-	-	-	-
	Insgesamt	44	41	38	37	1	-	-	-	-	-	-
Insgesamt	männlich	239583	239985	241812	240485	241227	244733	246013	243680	242660	245182	250073
	weiblich	241490	243861	247078	248175	252838	256749	259233	255504	254544	258694	268540
	Insgesamt	481073	483846	488890	488660	494065	501482	505246	499184	497204	503876	518613

Personalgruppen nach Beschäftigungsverhältnis Geschlecht			2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dozenten und Assistenten	männlich		3317	2857	2676	2559	2323	2361	2134	2113	2101	2179
	weiblich		1545	1349	1362	1340	1295	1332	1297	1287	1298	1390
	Insgesamt		4862	4206	4038	3899	3618	3693	3431	3400	3399	3569
Wissenschaftliche und künstlerische Mitarbeiter	männlich		82162	89207	94585	96939	99443	102701	104059	104321	105072	108377
	weiblich		51335	56920	61912	65152	68279	72000	73469	75330	77057	79670
	Insgesamt		133497	146127	156497	162091	167722	174701	177528	179651	182129	188047
Lehrkräfte für besondere Aufgaben	männlich		4070	4207	4347	4335	5033	4898	4676	4618	4758	4881
	weiblich		3804	4036	4205	4289	4879	4954	4980	5187	5277	5470
	Insgesamt		7874	8243	8552	8624	9912	9852	9656	9805	10035	10351
Sonstiges Personal für Lehre und Forschung	männlich		-	-	-	-	-	-	-	-	-	-
	weiblich		-	-	-	-	-	-	-	-	-	-
	Insgesamt		-	-	-	-	-	-	-	-	-	-
Insgesamt	männlich		257459	276648	290844	298257	307814	317102	323924	325720	327623	333011
	weiblich		279876	296716	310838	320976	332207	344974	351222	358665	363740	371596
	Insgesamt		537335	573364	601682	619233	640021	662076	675146	684385	691363	704607

Figure 3: German teaching personal in universities and universities of applied sciences through the years 1997 - 2017 based on [Ger17]

The following sections 1 and 2 refer to the results evaluated in Chapter 10 for the EIST course in the summer semester 2016 and summer semester 2017 [1].

1 Questionnaire Results for EIST 16

Question

From where did you usually attend the lecture?		
Answer	# of Votes	Percentage
lecture hall	143	60.08%
live stream	86	36.13%
secondary lecture hall	9	3.78%

Table 1: Results of question #A6 after the EIST summer semester 2016.

Question

In class interaction: [Did you like that we interactively updated slides and other lecture material to remove mistakes and add further comments?]		
Answer	# of Votes	Percentage
very much	108	45.38%
much	65	27.31%
moderately	36	15.13%
slightly	13	5.46%
not at all	16	6.72%
no answer	0	0.0%

Table 2: Results of question #B1 after the EIST summer semester 2016.

[1] A machine readable version of all answered questionnaires of the EIST course during the summer semester 2016 and summer semester 2017 can be found at this public URL: `https://tinyurl.com/amati-questionnaire`

Question		
Morning Quiz [Did you like the morning quizzes as a refresher for the last lecture?]		
Answer	# of Votes	Percentage
very much	108	45.38%
much	81	34.03%
moderately	39	16.39%
slightly	7	2.94%
not at all	3	1.26%
no answer	0	0.0%

Table 3: Results of question #B4/1 after the EIST summer semester 2016.

Question		
Morning Quiz [Would you like to be tested before the lecture starts on the upcoming material so the instructor can adapt the content accordingly ?]		
Answer	# of Votes	Percentage
very much	66	27.73%
much	78	32.77%
moderately	53	22.27%
slightly	27	11.34%
not at all	14	5.88%
no answer	0	0.0%

Table 4: Results of question #B4/2 after the EIST summer semester 2016.

Question		
How much did the given Tools distract you while following the lecture?[Slack]		
Answer	# of Votes	Percentage
very much	34	14.29%
much	42	17.65%
moderately	59	24.79%
slightly	50	21.01%
not at all	53	22.27%
no answer	0	0.0%

Table 5: Results of question #C3 after the EIST summer semester 2016.

Question		
How much did the given Tools help you to get a proper answer to your question:[Slack]		
Answer	# of Votes	Percentage
very much	56	23.53%
much	51	21.43%
moderately	55	23.11%
slightly	21	8.82%
not at all	9	3.78%
no answer	46	19.33%

Table 6: Results of question #C7 after the EIST summer semester 2016.

Question		
Considering new features to be implemented onto AMATI, Which features sound the most promising to you?[Generating a Quizduell to play Questions given against your collegues]		
Answer	# of Votes	Percentage
very much	79	33.19%
much	49	20.59%
moderately	54	22.69%
slightly	23	9.66%
not at all	33	13.87%
no answer	0	0.0%

Table 7: Results of question #C10 after the EIST summer semester 2016.

Question		
Rate the following features in AMATI by your personal preference: [Student Questions]		
Answer	# of Votes	Percentage
very much	41	17.23%
much	85	35.71%
moderately	79	33.19%
slightly	17	7.14%
not at all	16	6.72%
no answer	0	0.0%

Table 8: Results of question #C8/1 after the EIST summer semester 2016.

Question		
Rate the following features in AMATI by your personal preference: [Teacher Questions]		
Answer	# of Votes	Percentage
very much	37	15.5%
much	87	36.55%
moderately	81	34.03%
slightly	17	7.14%
not at all	16	6.72%
no answer	0	0.0%

Table 9: Results of question #C8/2 after the EIST summer semester 2016.

2 Questionnaire Results for EIST 17

Question		
How much did the given tools distract you while following the lecture? [Question Wall]		
Answer	# of Votes	Percentage
very much	14	6.19%
much	20	8.85%
moderately	42	18.58%
slightly	71	31.42%
not at all	61	26.99%
no answer	18	7.96%

Table 10: Results of question #C3 after the EIST summer semester 2017.

Question		
Would you recommend using the following tools in other courses? [Slack + AMATI]		
Answer	# of Votes	Percentage
yes	113	50.00%
no	33	14.60%
uncertain	65	28.76%
no answer	15	6.64%

Table 11: Results of question #C4/1 after the EIST summer semester 2017.

Question		
Would you recommend using the following tools in other courses? [Slack without AMATI]		
Answer	# of Votes	Percentage
yes	95	42.04%
no	49	21.68%
uncertain	63	27.88%
no answer	19	8.41%

Table 12: Results of question #C4/2 after the EIST summer semester 2017.

Question		
In the beginning of the semester: Did using multiple projectors showing different content distract you from following the lecture		
Answer	# of Votes	Percentage
very much	9	3.98%
much	12	5.31%
moderately	43	19.03%
slightly	57	25.22%
not at all	105	46.46%
no answer	0	0.00%

Table 13: Results of question #C5 after the EIST summer semester 2017.

Question		
After a few lectures using multiple projectors: Did using multiple projectors showing different content distract you from following the lecture		
Answer	# of Votes	Percentage
very much	4	1.77%
much	9	3.98%
moderately	26	11.50%
slightly	42	18.58%
not at all	145	64.16%
no answer	0	0.00%

Table 14: Results of question #C6 after the EIST summer semester 2017.

Question		
Do you prefer questions being answered via Slack & AMATI compared to the professor answering questions directly?		
Answer	# of Votes	Percentage
yes	106	46.90%
no	80	35.40%
no answer	40	17.70%

Table 15: Results of question #B2 after the EIST summer semester 2017.

Question		
Do you prefer questions being asked via Slack & AMATI compared to asking the professors directly?		
Answer	# of Votes	Percentage
yes	136	60.18%
no	60	26.55%
no answer	30	13.27%

Table 16: Results of question #B4 after the EIST summer semester 2017.

Question		
Did you get an answer to your question in a timely manner using SLACK & AMATI		
Answer	# of Votes	Percentage
yes	101	44.69%
no	23	10.18%
no answer	102	45.13%

Table 17: Results of question #D1 after the EIST summer semester 2017.

Question		
Did the answers provided help you to understand concepts, and therefore allowed you to keep following the lecture content, e.g. not feeling left behind in class.		
Answer	# of Votes	Percentage
yes	122	53.98%
no	34	15.04%
no answer	70	30.97%

Table 18: Results of question #D3 after the EIST summer semester 2017.

Question		
Did you ask more questions using AMATI instead of raise of hand?		
Answer	# of Votes	Percentage
yes	99	43.81%
no	53	23.45%
no answer	74	32.74%

Table 19: Results of question #D4 after the EIST summer semester 2017.

Question		
The answers provided through AMATI helped you understand the lecture content better		
Answer	# of Votes	Percentage
strongly agree	19	8.41%
agree	102	45.13%
neutral	63	27.88%
disagree	13	5.75%
strongly disagree	3	1.33%
no answer	26	11.50%

Table 20: Results of question #D5 after the EIST summer semester 2017.

Question		
The resources provided by AMATI help you to prepare for the exam.		
Answer	# of Votes	Percentage
strongly agree	6	2.65%
agree	45	25.22%
neutral	72	31.86%
disagree	29	12.83%
strongly disagree	15	6.64%
no answer	47	20.80%

Table 21: Results of question #D6 after the EIST summer semester 2017.

3 Questionnaire used for EIST 16/17

The questionnaire for the questionnaires used during the EIST summer semester 2016 and summer semester 2017 lectures can be found below.

Section A: General Info

A1. Please select your course of studies:

- Automotive Software Engineering, Master ☐
- Bauingenieurwesen, Bachelor ☐
- Bauingenieurwesen, Master ☐
- Biochemie, Master ☐
- BioInformatik, Bachelor ☐
- Computational Science and Engineering, Master ☐
- Elektrotechnik und Informationstechnik, Bachelor ☐
- Elektrotechnik und Informationstechnik, Master ☐
- Elektrotechnik und Informationstechnik, sonstige ☐
- Informatik, Aufbaustudium ☐
- Informatik, Master ☐
- Informatik, sonstiges ☐
- Informatik,Bachelor ☐
- Informatik: Games Engineering, Bachelor ☐
- Ingenieurwissenschaften (MSE), Bachelor ☐
- Maschinenbau und Management ☐
- Maschinenwesen, Bachelor ☐
- Maschinenwesen, Master ☐
- Mathematical Finance and Actuarial Science ☐
- Mathematik, Bachelor ☐
- Mathematik, Informatik Bachelor ☐
- Mathematik, Master ☐
- Mathematik, Sport Bachelor ☐
- Mechatronik und Informationstechnik ☐
- Physik (Biophysik), Master ☐
- Physik, Bachelor ☐
- Power Engineering, Master ☐

- [ ] Robotics, Cognition, Intelligence, Master
- [ ] Studium, MINT
- [ ] Technologie und Biotechnologie der Lebensmittel, Master
- [ ] Technologie- u. Managementorientierte BWL, Bachelor
- [ ] Technologie- u. Managementorientierte BWL, Master
- [ ] Technologie- u. Managementorientierte BWL, sonstige
- [ ] Umweltingenieurwesen, Bachelor
- [ ] Wirtschaft mit Technologie, Master
- [ ] Wirtschaftsinformatik, Master
- [ ] Wirtschaftswissenschaften für Naturwissenschaftler, Master
- [ ] Other

A2. In which Semester are you right now?

- [ ] 1
- [ ] 2
- [ ] 3
- [ ] 4
- [ ] 5
- [ ] 6
- [ ] 6+

A3. How frequently did you attend the course? (20 Lectures)

- [ ] Very Frequently (more than 18)
- [ ] Frequently (more than 15)
- [ ] Occasionally (more than 10)
- [ ] Rarely (less than 10)
- [ ] Very Rarely (less than 5)
- [ ] Never

A4. **When you attended a lecture, how often did you use Moodle to access lecture relevant content?**

- Very Frequently ☐
- Frequently ☐
- Occasionally ☐
- Rarely ☐
- Very Rarely ☐
- Never ☐

A5. **Considering participation in the morning quizzes; How often did you participate in the given morning quizzes?**

- Very Frequently ☐
- Frequently ☐
- Occasionally ☐
- Rarely ☐
- Very Rarely ☐
- Never ☐

A6. **From where did you usually attend the lecture?**

- Main lecture hall ☐
- Secondary lecture hall ☐
- Live streaming ☐

A7. **Given the fact that you watched the lecture over the livestream, how would rate the following features:**

	very good	good	average	poor	very poor
the quality of the streaming	☐	☐	☐	☐	☐
participation to exercises	☐	☐	☐	☐	☐
communication with the lecturer	☐	☐	☐	☐	☐

A8. **Given the fact that you attended the class in person - How would you rate the help from the tutors in your hall?**

- very good ☐
- good ☐
- average ☐
- poor ☐
- very poor ☐

A9. **Given the fact that you watched the lecture over the livestream, how often did you use the introduced feedback tools to participate remotely:**

	Very Frequently	Frequently	Occasionall y	Rarely	Very Rarely	Never
Slack	☐	☐	☐	☐	☐	☐
Infeedbruegge	☐	☐	☐	☐	☐	☐

Section B: Methodology

B1. **In class interaction:**

	Very much	Much	Moderately	Slightly	Not at all
Did you like the possibility to receive interactive answers for your questions using different tools?	☐	☐	☐	☐	☐
Did you find to get answers to your questions in a timely manner when using the different tools presented?	☐	☐	☐	☐	☐
Did you like that we interactively updated slides and other lecture material to remove mistakes and add further comments?	☐	☐	☐	☐	☐

B2. **Please rate how much you like the following exercise concepts based on your experience:**

	Very much	Much	Moderately	Slightly	Not at all
Interactive mixed Class/Exercise	☐	☐	☐	☐	☐
Centralized Tutorial	☐	☐	☐	☐	☐
Small Tutor Groups	☐	☐	☐	☐	☐

B3. **Live Exercises**

	Very much	Much	Moderately	Slightly	Not at all
Did you like that we showed student solutions to exercises and discussed critical problems?	☐	☐	☐	☐	☐

B4. **Morning Quiz**

	Very much	Much	Moderately	Slightly	Not at all
Did you like the moring quizzes as a refresher for the last lecture?	☐	☐	☐	☐	☐
Would you like to be tested before the lecture starts on the upcoming material so the lecturer can adapt the content accordingly ?	☐	☐	☐	☐	☐

B5. **Did you read the given questions of this questionaire carefully before answering?**

Yes ☐

No ☐

B6. **Is there anything else you'd like to tell us according to methodologies?**

Section C: Tools Evaluation

C1. **How would you evaluate the usability of...:**

	very good	good	average	poor	very poor
Slack	☐	☐	☐	☐	☐
Moodle	☐	☐	☐	☐	☐
Infeedbruegge	☐	☐	☐	☐	☐
Exercisebruegge	☐	☐	☐	☐	☐

C2. **How easy was it for you to setup the given tools to start participating during class/exercises?**

	very easy	easy	average	difficult	very difficult
Eclipse	☐	☐	☐	☐	☐
Visual Paradigm	☐	☐	☐	☐	☐
Git	☐	☐	☐	☐	☐
SourceTree	☐	☐	☐	☐	☐
Slack	☐	☐	☐	☐	☐

	very easy	easy	average	difficult	very difficult
Moodle	☐	☐	☐	☐	☐
Infeedbruegge	☐	☐	☐	☐	☐
Exercisebruegge	☐	☐	☐	☐	☐

C3. How much did the given Tools distract you while following the lecture?

	Very much	Much	Moderately	Slightly	Not at all
Slack	☐	☐	☐	☐	☐
Moodle	☐	☐	☐	☐	☐
Infeedbruegge	☐	☐	☐	☐	☐
Exercisebruegge	☐	☐	☐	☐	☐

C4. Would you recommend using the following tools in other courses

	Very much	Much	Moderately	Slightly	Not at all
Slack	☐	☐	☐	☐	☐
Moodle	☐	☐	☐	☐	☐
Infeedbruegge	☐	☐	☐	☐	☐
Exercisebruegge	☐	☐	☐	☐	☐

C5. Did the fact of using many different tools, sometimes even simultaneously distract you from following the lecture?

- ☐ Very much
- ☐ Much
- ☐ Moderately
- ☐ Slightly
- ☐ Not at all

C6. How much did the given tool help you to communicate to the instructor / teaching assistant?

	Very much	Much	Moderately	Slightly	Not at all
Slack	☐	☐	☐	☐	☐
Moodle	☐	☐	☐	☐	☐

	Very much	Much	Moderately	Slightly	Not at all
Infeedbruegge	☐	☐	☐	☐	☐
Exercisebruegge	☐	☐	☐	☐	☐

C7. How much did the given Tools help you to get a proper answer to your question:

	Very much	Much	Moderately	Slightly	Not at All	No answer
Slack	☐	☐	☐	☐	☐	☐
Moodle	☐	☐	☐	☐	☐	☐
Infeedbruegge	☐	☐	☐	☐	☐	☐
Exercisebruegge	☐	☐	☐	☐	☐	☐

C8. Rate the following features in infeedbruegge by your personal preference:

	Very much	Much	Moderately	Slightly	Not at all
Lecture Timer	☐	☐	☐	☐	☐
Student Questions	☐	☐	☐	☐	☐
Teacher Questions	☐	☐	☐	☐	☐
Student Mood	☐	☐	☐	☐	☐

C9. Which features would you like to add to infeedbruegge to support you even better while participating in class and during exercises?

C10. Considering new features to be implemented onto infeedbruegge, Which features sound the most promising to you?

	Very much	Much	Moderately	Slightly	Not at all
Generating a Student lecture report based on the results given in the live quizzes	☐	☐	☐	☐	☐
Generating a Quizduell to play Questions given against your collegues	☐	☐	☐	☐	☐
Integrating the Live Stream and lecture material	☐	☐	☐	☐	☐

C11. **If you have any further comments about our Teaching Methodology feel free to give us additional feedback here:**

Section D: Live Streaming

D1. **How useful were the following lecture features to you?**

	Very much	Much	Moderately	Slightly	Not at all
Live Streaming in different halls	☐	☐	☐	☐	☐
Live Streaming from the livestreaming web platform	☐	☐	☐	☐	☐
Lecture recording	☐	☐	☐	☐	☐

D2. **We provided you with different recordings of the lectures.**

A livestream version (uncutted and untouched) A owncloud version (cutted and remastered)

Please rate the impact on your viewing pleasure according the individual versions

	very good	good	average	poor	very poor
Live Version	☐	☐	☐	☐	☐
Edited Version (with cuts)	☐	☐	☐	☐	☐

D3. **Given the lecture recordings how happy have you been with the audio and video quality, respectively?**

	very good	good	average	poor	very poor
Audio	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐

D4. **Using the livestream DURING the lecture, on which devices did you consume the content?**

	Very Frequently	Frequently	Occasionall y	Rarely	Very Rarely	Never
Laptop/Mobile Computer	☐	☐	☐	☐	☐	☐

	Very Frequently	Frequently	Occasionall y	Rarely	Very Rarely	Never
Desktop Computer	☐	☐	☐	☐	☐	☐
Tablet	☐	☐	☐	☐	☐	☐
Mobile/Smartphone	☐	☐	☐	☐	☐	☐

D5. Using the recorded video AFTER the lecture, on which devices did you consume the content?

	Very Frequently	Frequently	Occasionall y	Rarely	Very Rarely	Never
Laptop/Mobile Computer	☐	☐	☐	☐	☐	☐
Desktop Computer	☐	☐	☐	☐	☐	☐
Tablet	☐	☐	☐	☐	☐	☐
Mobile/Smartphone	☐	☐	☐	☐	☐	☐

D6. If you have any further comments about our Live Streaming offers feel free to give us additional feedback here:

Section A: General

A1. Please select your course of studies:

If your field of study is not included please select "Other"

- [ ] Automotive Software Engineering, Master
- [ ] Bauingenieurwesen, Bachelor
- [ ] Bauingenieurwesen, Master
- [ ] Biochemie, Master
- [ ] BioInformatik, Bachelor
- [ ] Computational Science and Engineering, Master
- [ ] Elektrotechnik und Informationstechnik, Bachelor
- [ ] Elektrotechnik und Informationstechnik, Master
- [ ] Elektrotechnik und Informationstechnik, sonstige
- [ ] Informatik, Aufbaustudium
- [ ] Informatik, Master
- [ ] Informatik, sonstiges
- [ ] Informatik,Bachelor
- [ ] Informatik: Games Engineering, Bachelor
- [ ] Ingenieurwissenschaften (MSE), Bachelor
- [ ] Maschinenbau und Management
- [ ] Maschinenwesen, Bachelor
- [ ] Maschinenwesen, Master
- [ ] Mathematical Finance and Actuarial Science
- [ ] Mathematik, Bachelor
- [ ] Mathematik, Informatik Bachelor
- [ ] Mathematik, Master
- [ ] Mathematik, Sport Bachelor
- [ ] Mechatronik und Informationstechnik
- [ ] Physik (Biophysik), Master
- [ ] Physik, Bachelor

Power Engineering, Master ☐

Robotics, Cognition, Intelligence, Master ☐

Studium, MINT ☐

Technologie und Biotechnologie der Lebensmittel, Master ☐

Technologie- u. Managementorientierte BWL, Bachelor ☐

Technologie- u. Managementorientierte BWL, Master ☐

Technologie- u. Managementorientierte BWL, sonstige ☐

Umweltingenieurwesen, Bachelor ☐

Wirtschaft mit Technologie, Master ☐

Wirtschaftsinformatik, Bachelor ☐

Wirtschaftsinformatik, Master ☐

Wirtschaftswissenschaften für Naturwissenschaftler, Master ☐

Other ☐

A2. In which Semester are you right now?

1 ☐

2 ☐

3 ☐

4 ☐

5 ☐

6 ☐

6+ ☐

Early Student / Schülerstudent ☐

A3. How frequently did you attend the course? (In the lecture hall or via Livestream.com)

Every Week ☐

I missed 2 or fewer ☐

I missed 5 or fewer ☐

I only attended 2-3 lectures ☐

Never ☐

A4. How did you attend the lecture?

If you used both methods please select the one you used more often

- In the lecture hall ☐
- Via livestream.com ☐
- lecture recordings ☐

A5. Did you use AMATI to ask questions?

AMATI is integrated in slack with the CAQAS bot application. If you asked a question in one of the question channels in slack answer with YES.

- Yes ☐
- No ☐

A6. How useful were the following lecture features to you?

	Very much	Much	Moderately	Slightly	Not at all
Livestream	☐	☐	☐	☐	☐
Recording	☐	☐	☐	☐	☐
Slack	☐	☐	☐	☐	☐
Slack + AMATI	☐	☐	☐	☐	☐

A7. Did you use the lecture recordings?

- Yes ☐
- No ☐

Section B: Methodology

B1. Please rate how much you like the following exercise concepts based on your experience

	very good	good	average	poor	very poor
Tutorial session (like this semester)	☐	☐	☐	☐	☐
In-class exercises	☐	☐	☐	☐	☐
Tutorial session + Exercise class (Zentralübung)	☐	☐	☐	☐	☐

B2. Do you prefer questions being answered via Slack & AMATI compared to the professor answering questions directly?

- Yes ☐
- No ☐

B3. **If you have any further comments about our Teaching Methodology feel free to give us additional feedback here:**

B4. **Do you prefer questions being asked via Slack & AMATI compared to asking the professors directly?**

Yes ☐

No ☐

Section C: Tool Evaluation

C1. **What is your general impression of the tools used in EIST**

AMATI refers to the bot integration slack as well as the wallboard during lectures and the question reports generated after lectures.

	very good	good	average	poor	very poor
Slack + AMATI	☐	☐	☐	☐	☐
Slack without AMATI	☐	☐	☐	☐	☐
exercisebruegge	☐	☐	☐	☐	☐
moodle	☐	☐	☐	☐	☐

C2. **How easy was it for you to setup the given tools to start participating during class/exercises?**

	very easy	easy	average	hard	very hard
Slack	☐	☐	☐	☐	☐
exercisebruegge	☐	☐	☐	☐	☐
moodle	☐	☐	☐	☐	☐

C3. **How much did the given tools distract you while following the lecture?**

	Very much	Much	Moderately	Slightly	Not at all
Slack + AMATI	☐	☐	☐	☐	☐
Question Wall	☐	☐	☐	☐	☐
exercisebruegge	☐	☐	☐	☐	☐

	Very much	Much	Moderately	Slightly	Not at all
moodle	☐	☐	☐	☐	☐

C4. Would you recommend using the following tools in other courses?

	Yes	Uncertain	No
Slack + AMATI	☐	☐	☐
Slack without AMATI	☐	☐	☐
exercisebruegge	☐	☐	☐
moodle	☐	☐	☐

C5. In the beginning of the semester:

Did using multiple projectors showing different content distract you from following the lecture

- Very much ☐
- Much ☐
- Moderately ☐
- Slightly ☐
- Not at all ☐

C6. After a few lectures using multiple projectors:

Did using multiple projectors showing different content distract you from following the lecture

- Very much ☐
- Much ☐
- Moderately ☐
- Slightly ☐
- Not at all ☐

C7. How much did the given communication channels help you to get in contact with the instructor / teaching assistant?

	Very much	Much	Moderately	Slightly	Not at all
Slack / AMATI / CAQAS BOT	☐	☐	☐	☐	☐
Moodle	☐	☐	☐	☐	☐
Mail	☐	☐	☐	☐	☐

	Very much	Much	Moderately	Slightly	Not at all
Phone	☐	☐	☐	☐	☐
After Class Discussion	☐	☐	☐	☐	☐
Tutor Groups	☐	☐	☐	☐	☐

C8. How much did the given Tools help you to get a satisfying answer to your question?

	Very much	Much	Moderately	Slightly	Not at all
Slack / AMATI / CAQAS BOT	☐	☐	☐	☐	☐
Moodle	☐	☐	☐	☐	☐
Mail	☐	☐	☐	☐	☐
Phone	☐	☐	☐	☐	☐
After Class Discussion	☐	☐	☐	☐	☐

C9. What kind of recording do you prefer?

- Edited and remastered, but later release ☐
- The unedited livestream recording, faster release ☐

C10. What do you think of the quality of the edited and remastered lecture recordings?

- very good ☐
- good ☐
- average ☐
- poor ☐
- very poor ☐

Section D: AMATI specific

D1. Did you get an answer to your question in a timely manner using SLACK & AMATI

- Yes ☐
- No ☐

D2. **Rate the following features in AMATI / CAQAS by your personal preference:**

	very good	good	average	poor	very poor
Wallboard	☐	☐	☐	☐	☐
Question/Answer Report	☐	☐	☐	☐	☐
Slack Q&A including lecture slides	☐	☐	☐	☐	☐
Peer Review answers from Colleagues	☐	☐	☐	☐	☐
Receive personal message with your Question and corresponding Answer	☐	☐	☐	☐	☐

D3. **Did the answers provided help you to understand concepts, and therefore allowed you to keep following the lecture content, e.g. not feeling left behind in class.**

Yes ☐

No ☐

D4. **Did you ask more questions using AMATI instead of raise of hand?**

Yes ☐

No ☐

D5. **The answers provided through AMATI helped you understand the lecture content better**

strongly agree ☐

agree ☐

neutral ☐

disagree ☐

strongly disagree ☐

D6. **The resources provided by AMATI help you to prepare for the exam.**

strongly agree ☐

agree ☐

neutral ☐

disagree ☐

strongly disagree ☐

D7. **What is your general opinion of the AMATI tool set (Slack integration, Wallboard, Question Reports)**

1 is low, 5 is high.

1 ☐
2 ☐
3 ☐
4 ☐
5 ☐

Section E: email

E1. **If you want to participate in the price drawing please submit an email address here.**

Thank you for participating in the survey. Your feedback helps improving the lecture for future iterations.