Metacognitive Support in University Lectures Provided via Mobile Devices

How to Help Students to Regulate Their Learning Process during a 90-minute Class

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Abstract: Even though classical lectures at universities are criticized for lacking interactivity and treating students like passive receptors of information they are still very popular. Due to the big amount of students, interaction between teacher and students is difficult to realize. Several projects address this problem by offering technical solutions which aim at increasing the interactivity during classes or lectures – classic clicker-systems as well as solutions in which students use their own smartphones, netbooks or tablet-PCs. Based on research on self-regulated learning (SRL) processes we developed the already existing tools one step further: instead of only providing questions we designed Auditorium Mobile Classroom Service (AMCS) – a program which offers several possibilities to interact during a lecture. AMCS supports students to regulate their own learning process during the lecture. Learning questions are one core element to support them. On the basis of the results of the learning questions specific advices and hints are sent to the students' smartphones or notebooks. The features increase the interactivity between the content and students and the interaction in the lecture hall. In the present article the program AMCS is described. Furthermore we report first experiences from a field test in a university lecture.

1 INTRODUCTION

Lectures are still an important form of teaching courses at universities. They aim to expand students' knowledge through the structured presentation of expertise from a teacher. This form of teaching has been criticized for offering too little interaction between teachers and students. Learning as an active, constructive and highly individual process (Seel, 2003) is almost impossible in huge lectures. As a consequence, students experience severe difficulties – they do not manage to build adequate mental models of the taught domain.

There are several approaches to increase the interactivity in lectures. The spectrum ranges from simple voting systems to the method of peer instruction (Mazur, 1997). A large variety of systems especially useful for implementing learning questions in lectures are subsumed under the concept "audience response systems" or "clickers". Audience response systems provide feedback to the lecturer by giving the audience the possibility to participate during the class by voting on questions. By presenting questions during the class students get more involved in the lecture and the lecturer in turn gets some information about the audience's knowledge and attitudes. Almost all of these systems work as follows: the lecturer defines a question before starting the class; during the lecture the question is presented on the screen and the students are asked to answer via special technical devices (clickers) or their smartphones; all answers are aggregated and immediately pictured on the presentation-screen. The lecturer can include the answers from the audience into the lecture – provide feedback to the audience or adapt the lecture to special interests or needs. There are some studies showing that audience response systems are capable of increasing the interactivity in lectures and leading to an improvement in academic achievement (e.g. Mayer et al., 2009). A prerequisite for these positive effects seem to be that the application is accompanied with strategies that engage students in deeper processing (Brady et al., 2013). For example,

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Lantz and Stawiski (2014) point out that obtaining feedback after working on the questions is crucial for an improvement in learning.

We took existing systems like SMILE (Weber & Becker, 2013) as a starting point and combined first experiences with the results of the research on self-regulated learning and learning questions. On this basis we extended the concept of classical audience response systems. Our main goal is to support students during large university lectures in achieving their personal learning goals. On the basis of SRL models we developed a system to provide interactive learning questions, cognitive and metacognitive prompts to students in university lectures. With Auditorium Mobile Classroom Service (AMCS) the lecturer designs in advance of the class learning questions with feedback and messages with additional information. These messages and learning questions are delivered during the lecture in order to facilitate successful regulation of the learning process of each of the participants.

From a technical perspective we added one direction of communication – in contrast to existing systems AMCS does not only give the students the possibility to vote during the lecture, the professor gets the possibility to communicate to them during the class as well. That way the lecture is designed as an individual adaptive learning process. In the following sections the core elements of AMCS are described.

2 FEATURES OF AMCS

Models of self-regulated learning (e.g., Zimmerman, 2000) identify the requirements that must be met by students at different points in the learning process. Zimmerman (2000) assumes that the forethought phase, the performance phase and the self-reflection phase are recurrent at different levels during a learning process. The goal orientation, attribution style and individual differences in prior knowledge, for example, have an impact on the forethought phase and the planning of the learning process. Depending on these variables students may differ in preparing for university lectures. Planning and preparing for the lecture is crucial for the successful knowledge acquisition. During the performance phase the diverse information needs to be processed. This includes the use of pre-selected learning strategies and the maintenance of motivation and attention. In the self-reflection or evaluation phase, learners should reflect on their learning process and achievement and derive implications for future learning activities. Processes during the performance and the self-reflection phase are influenced by individual differences as well. Depending on the capability to concentrate, the personal goals and interests learners master the demands of these two phases differently. This results in different learning outcomes. AMCS aims at supporting students in self-regulated learning taking into account that individual differences of the students play a decisive role.

In the following section the features of AMCS are presented. All instructional interventions are delivered via mobile devices (netbooks, smartphones, tablets) during the lecture.

2.1 Interests / Personal Goals

At the beginning of the lecture students are asked for their personal goals and interests. Why are they attending the lecture? Are they interested in the topic or focused on passing the exam? The goals must be taken into account when supporting students in regulation during the lecture. Therefore, the information collected is used as a basis for metacognitive prompts. Metacognitive prompts are instructions that are sent to the mobile devices of the students during the lecture. They contain information which helps them to regulate their personal learning process depending on their goals and interests. Besides, students shall be encouraged by this short survey at the beginning of the lecture, to be clear about their goals and interests.

2.2 Learning Questions at the Beginning, in the Middle and at the End of the Lecture

Interactive learning questions are implemented to support the learning process both on a cognitive and a metacognitive level. Located at the beginning, in the middle and at the end of the lecture they assist students in an active engagement with the content. Prerequisite for the effectiveness of learning questions is the consideration of certain design rules. Körndle, Narciss and Proske (2004) identified four dimensions, which can be systematically constructed: 1) format, 2) content, 3) cognitive operations necessary to solve the question, and 4) interactivity. Within AMCS the question format multiple-choice is available. The interactivity goes beyond already existing tools. AMCS allows designers to implement a two-step feedback algorithm defining specific feedback for any option. In contrast to other audience response systems learners receive individual feedback on their mobile devices. They can answer the learning questions twice before the correct option is displayed. Feedback contains information whether the answer is correct or not and in case of an incorrect answer hints on how to go on.

Learning questions at the beginning aim at activating prior knowledge. In addition, the requirements of the lecture are communicated through the learning questions and the attention of the students is guided to specific content. After half of the lecture, the students can use the learning questions to practice the recently learned concepts and to get feedback on their level of knowledge progress. At the end of the class learning questions again aim at practicing relevant concepts and are useful for the self-evaluation of the learning process. As learners obtain feedback on their level of knowledge they can draw conclusions for future events - concerning the regulation of attention and motivation as well as the application of learning strategies. In contrast to already existing audience response systems AMCS is accompanied with an instructional concept which contains interactive learning questions as a core element and theoretically deduced how and when to implement them in the lecture.

2.3 Metacognitive Prompts

During the lecture metacognitive prompts are sent automatically to the students. They aim at supporting the students in reaching their personal learning goals. As they address regulation processes on a more abstract level we named them "metacognitive prompts". The prompts are delivered depending on personal goals and characteristics of the student (e.g., learning goal orientation, exam preparation or interest in the topic) and depending on how they did in the learning questions.

In advance of the lecture the professor designs messages containing helpful information and prompts for different goals (e.g., exam preparation vs. research interest) and different motivational states (no interest in the topic at all vs. really curious about the topic). At the beginning the students are asked about their goals and motivation with the help of a short questionnaire. Based on their answers they get adaptive metacognitive prompts during the lecture. An example of a metacognitive prompt, which intents to help the students to adapt their learning behaviour to their goal "passing the exam" is the following:

"On the following slide the concept X is explained. This concept is relevant for the exam. A question of how it is raised repeatedly in the oral examination is, for example: Why is it important to apply concept X when starting the process?" Students are required to select and process content, which is relevant for their personal learning goals. At the same time the personal goals can significantly differ within a group of students attending the same lecture. Thus, it results to be difficult for the lecturer to address all the different goals in one session. As a result students fail in selecting relevant information and differentiate between important and marginal content. The messages sent by AMCS containing metacognitive prompts introduce adaptive support to students in order to reach their personal learning goals.

2.4 Cognitive Prompts - Individual Adaptive Feedback during the Lecture

Learning questions at the beginning of the lecture and in the middle are not only interventional tools to support students in knowledge construction. They also deliver diagnostic information on the state of knowledge acquisition of the students. This information can be used to promote knowledge building and further develop students' mental models.

Learning questions with several response options offer the possibility to incorporate typical misconceptions about concepts and theories. If the mental model contains misconceptions and the incorrect answer is chosen, the cognitive prompts can support students in correcting the misconception and overcome these obstacles. AMCS initiates corrective processes by sending the student a cognitive prompt at the moment the misconception is explained by the lecturer.

If a student, for example, selects an incorrect option to the first learning question at the beginning of the lecture, then he gets the following message when the lecturer is explaining slide number 13 of his presentation:

"You have made a mistake in the first learning question at the beginning. For some reason you thought that concept X is the answer to the question. What it really means is explained by Prof. Y on the current slide."

The cognitive prompt should initiate behaviour which leads to the correction of the misconception. In order to do so it names the misconception and draws the attention to the explanation of the concept by the lecturer. These messages are referred to as cognitive prompts as they directly address concrete information and have the goal to stimulate information processing of specific content. They might also initiate regulation behaviour as the consequence of a corrected misconception can be changes in learning behaviour. Thus, the main difference to metacognitive prompts is the level of intended effects: cognitive prompts aim at integrating or correcting specific content, whereas metacognitive prompts put the focus on general regulatory mechanisms such as the maintenance of attention or the understanding of demands. It is also possible to combine both types of prompts.

2.5 Providing Further Material to the Students – Scripts, Links and Additional Texts

AMCS offers the possibility to provide further materials to the students. These include links, PDFs, and slides of the presentation. The materials can be chosen adaptively to the individual goals of the students and/or to their learning behaviour. An example of a message with further material for students who are thinking about doing research or writing their thesis in the field of the lecture is as follows:

"You have indicated at the beginning of the lecture that you are interested in writing a thesis on this topic. The chair is doing research on the topic which is presented on the current slide. You can find possible research queries for a Bachelor thesis on the subject under the following link: http:// .... "

2.6 Scripted Discussion – How to Animate Students to Ask Questions Which Are Helpful for Them

The sixth feature of AMCS applies during the time slot, which is normally reserved for a discussion. Both the auditorium and the lecturer exchange ideas and questions at the end of the lecture. By sending the students messages AMCS intends to initiate this exchange and involve students who normally do not participate in this interaction. In exceptional cases, the discussion may even be staged. Pro and counter-arguments could be distributed among the audience. One example for a message with a request for a comment that aims at starting the discussion is the following: "Stand up right now and ask the following question loudly into the room: What's the practical use of this theory?" The goal of this feature is to use the time reserved for discussion and interaction between the lecturer and the students in an optimal way.

3 PILOT STUDY

The AMCS prototype was tested in a 90-minute lecture on psychology. The evaluation had mainly three goals: we wanted to figure out if (1) the tool works properly during the lecture (Does the tool deliver messages and learning questions at the correct moments etc.?). Furthermore we aimed at (2) checking if the intervention is accepted by the students (Do students appreciate the usage of mobile devices with the reported features during the lecture?). Finally we wanted to investigate (3) whether AMCS is able to produce positive effects concerning motivation, concentration and achievement. We gained data to answer these questions from log-file analyses, self-reports of the students and achievement tests.

3.1 Technical Infrastructure

AMCS is based on a service-oriented system with different client applications for students and lecturers (see Figure 1). The students' client enables them to get prompts and questions during the class. The interventions are delivered via inbound and outbound messages on their smartphones or other Internet-enabled devices (tablets, netbooks or notebooks). They interact with the service via web based application over an REST-API. This has the advantage of platform independence over all device classes.

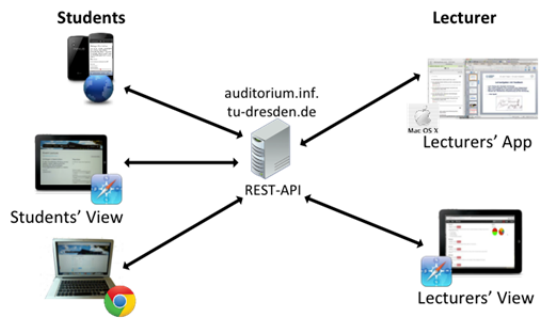

Figure 1: system architecture of AMCS.

The responses of the students are stored in a database on the Auditorium server. On this basis, learners receive messages which are sent automatically by the system. The timing of message dispatch is dependent on the actual presentation of the lecturer. Therefore it is necessary that the server communicates with the presentation device of the lecturer while the class is taken place. This synchronization with the presentation system (e.g., PowerPoint, Keynote or PDF) is done by the lecturers' app, which was implemented as native Mac OS X application as well as a desktop application for Windows. Within this application the lecturer defines in advance of the class on which presentation-slide which specific message will be sent or which questions have to be answered.

During the class the professor can use the lecturers' view of the AMCS web application to see how the students are doing. By observing the voting results and answers in real-time lecturers can adapt the pace of their presentation or address content which was not understand yet.

3.2 Method

Thirty students (10 men, 20 women, mean age: 25.8 years, SD: 5.1 years) from a German university participated in the field study. The sample size differed between 22 (all evaluation data including questionnaires and knowledge test) and 30 persons (log-files during the lecture – delivery of messages and learning questions) as some of the participants did not fill out the post-questionnaires. Within the sample smartphones (11), tablets (2), netbooks (9) and notebooks (7) were used (missing information for one participant).

The lecture was on the topic of self-regulated learning, which is regular part of the curriculum in the field of learning and instruction. Before starting with the lecture every participant was requested to answer the pre-questionnaire asking for interest in the topic and motivation to attend the lecture. Afterwards they received their personal login for the AMCS platform and the class started. At the end of the class participants answered the post-questionnaire containing several measurements about motivation, usability and a knowledge test.

3.3 Results

3.3.1 Technical Functionality

Nine persons reported that their devices work either with iOS or with OS X, 10 devices were based on windows operating systems and four on android. Seven participants did not report on which basis their devices work. The log-files from the data bank revealed that the 26 users assessed created 206 logs concerning the learning questions. In average 7.9 actions per person referring to the learning questions were documented. There were 67 entries in the database regarding the three questions at the beginning of the lecture (concerning the goals and interests of the students). As 26 users are registered it is clear that not all of the participants answered all questions. During the lecture 98 messages containing either cognitive prompts, metacognitive prompts, further information and material or suggestions for the discussion at the end were send to the mobile devices of the participants. The average of messages sent was 3.8 per participant.

The comments in the post-questionnaire revealed a number of technical problems which participants experienced during the session. One student was not able to connect and login into the system at all. Further comments addressed a mixture between languages in the user interface (2), that messages should be high lightened in some way (2), that the feedback algorithm can be improved (1), that there were technical problems with the learning questions at the end (1).

3.3.2 Acceptance

Participants were asked in the post-questionnaire if they would recommend the program and would like to work again with it. Twenty-one participants answered the questionnaire of six items. The mean value for the group is 3.76 (SD = .68) on a scale from 1 "I do not agree" to 5 "I fully agree". The item asking if they consider the functionalities useful (learning questions, messages and feedback to the lecturer) was rated 4.19 (SD = .68). The usability criteria "conformity with user expectations" (5 items; M = 5.8, SD = .93), "suitability for the task" (5 items; M = 5.3, SD = .86) and "self-description capability" (5 items; M = 4.7, SD = 1.00) were rated positively. The scale ranges from 1 "---" to 7 "+++".

The lecturer positively annotated that he could use his normal presentation (based on PowerPoint) and was able to see the results of the learning questions and questionnaires in real-time.

3.3.3 Motivation and Knowledge

Twenty-two participants answered the questionnaire on motivation, concentration and attention compared to normal lectures. Scales ranged from 1 "I do not agree" to 5 "I fully agree". Students rather agreed that their concentration (M = 3.55; SD = .79), attention (M = 3.39; SD = .72) and motivation (M = 4.09; SD = .71) was higher with AMCS. There was one item asking for an overall judgment on the lecture with AMCS compared to normal lectures. Participants of the field study rather agreed (M = 3.14, SD = 1.04) to the statement "By using mobile devices in this lecture I learned more than in normal lectures." Interests on self-regulated learning (n = 19; 7 items) and motivation to study (n=21, 3 items) before and after the lecture were assessed with questionnaires. There were no significant changes from pre to post (interest: $t(18) = -.57$, $p > .5$; motivation: $t(21) = -1.5$, $p = .15$). Both interest ($M_{pre} = 3.03$, $SD_{pre} = .68$; $M_{post} = 3.08$, $SD_{post} = .61$; scale ranging from 1 to 4) as motivation to study ($M_{pre} = 5.24$, $SD_{pre} = .59$; $M_{post} = 5.35$, $SD_{post} = .54$; scale ranging from 1 to 6) remained on a high level. Twenty-two students participated in the achievement test. Scores ranged from zero to eight points (the test has 10 items – one point for each item was given). The mean score was 3.96 (SD = 2.40).

4 CONCLUSIONS

Auditorium Mobile Classroom Service (AMCS) provides an opportunity to support students during university lectures. The six features aim at fostering regulation and mastering demands of self-regulating learning. The core elements of AMCS are derived from empirical studies (e.g., Kapp, Proske, Narciss, & Körndle, 2011) and theoretical considerations based on models of self-regulation (e.g. Zimmerman, 2000). The first test of the pilot is seen as a demonstration of how learning questions, cognitive and metacognitive prompts can be used in university lectures in order to support students in mastering the demands of this learning situation. Via mobile devices, university lectures are made adaptive – learning questions and individual prompts are tailored to the personal goals and learning processes of the students.

The interactivity is increased by interventions, which animate students to engage in content (learning questions) and by establishing a communication channel (via the mobile devices of the students), which allows the learning environment to interact with the students (via predefined prompts and messages by the lecturer).

The results of the pilot are of course limited and do not go beyond the examination of requirements necessary to generate learning effects. These requirements are for example technical functionalities and acceptance of the system and self-reported attention, concentration, motivation and achievement. The first evaluation suggests that the minimum requirements are met. The intervention was not perceived as distraction nor judged as difficult to use during the lecture. The usability of the system was rated as good and beside some technical problems students would recommend AMCS and further use it. First critical arguments could be refuted: the distraction of the usage of mobile devices during the lecture does not seem to constrain learning and the need of extensive computer literacy is not a requirement to use AMCS. Nevertheless the data is not sufficient. In future studies we want to test the system and its components in large lectures and empirically evaluate the effects of the single features.

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