Large-Class Teaching with Backstage

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Abstract

Purpose: Several challenges of today's higher education were motivations to reconsider the contents and formats of lectures and tutorials and to conceive the classroom communication system Backstage, a social media platform supporting a novel form of large-class teaching. This article reports on the challenges met, on the novel teaching form and on an evaluation of this teaching form.

Design/methodology/approach: The use of Backstage in two courses is evaluated. One of the courses has been specially adapted to promote student participation, the other course has been held in a traditional way. To investigate the usefulness and acceptance of Backstage in the given settings the data collected on Backstage and student responses in surveys are analyzed.

Findings: The results indicate that Backstage can foster interactivity and awareness in large-class lectures when used in combination with a teaching format that provides opportunities for and encourages lecture-relevant communication. Furthermore, students appreciated the use of Backstage..

Research limitations/implications: This article reports on a case study, which lacks generalizability. Further studies under controlled conditions and of the learning effectiveness of the approach are still outstanding.

Practical implications: This article describes an approach fostering a form of Active Learning in large classes. Since large classes are widespread in higher education, the approach has a considerable practical potential.

Originality/value: Similar results have not been published so far.

Keywords: Social Media, Technology-Enhanced Learning, Large-Class Teaching

Article classification: Case Study

1 Introduction

This article reports on an experiment in higher education. Several challenges were motivations to modify the contents of lectures, to redesign the formats of lectures and tutorials, and to conceive the social medium Backstage (Bry and Pohl 2014, Gehlen-Baum et al. 2011, Pohl et al. 2011) with the goal to provide technological support for a form of large class teaching that promotes a collaborative reflection of the students on the contents taught, supports immediate feedback and a social control of the communication through the student community.

This article first explains the reasons for reconsidering teaching formats: large classes (Cuseo 2007, Mulryan-Kyne 2010, Rocca 2010) and other structural difficulties, an accelerated pace of learning and changes among students (Roehling et al. 2011), the difficult choice of appropriate instruction methods, and new possibilities for teaching and learning that social media offer. Then this article describes how the teaching format has been modified and how the social medium Backstage has been designed so as to support the modified teaching format and to promote among students interactivity, awareness, and social control. Finally, this article reports on an evaluation of Backstage.

This article is an experience report on an approach to teaching and learning rooted in the teaching practice of Mathematics, Engineering and Natural Sciences. The findings dealt with in this article have been gained "in the field" and not under laboratory conditions. As a consequence, causalities between teaching methods and learning outcomes are uncertain. Nonetheless, the evaluation reported here shows that Backstage can achieve its goals, that is, promoting among students interactivity and awareness, provided an appropriate teaching format is selected.

This article consists of seven sections. Section 1 is this introduction. Section 2 reviews the literature on challenges met in today's higher education. Section 3 presents the didactic approach advocated for.
Section 4 reviews the literature on technology support of teaching and learning in lectures. Section 5 is a presentation of the social medium Backstage supporting the teaching form advocated for. Section 6 reports on a field evaluation of large class teaching using Backstage. Section 7 is the conclusion.

2 Challenges met by lecturers and students in large classes: A literature review

The teaching and learning experiment this article reports about has been motivated by challenges faced by students and lecturers in many higher education institutions:

- Large classes and other structural difficulties
- Accelerated pace of teaching
- Changes among students
- Choice of instruction methods

2.1 Large classes and other structural difficulties

In many higher education institutions, large classes are the most salient difficulty for students and lecturers alike. They are, however, just one of several structural difficulties:

- *Heterogeneous audiences* especially, but not only, in Bachelor curricula (Biggs 1999, Wolfam 2002, Mulryan-Kyne 2010, Biggs and Chang 2011 Chapter 1).
- *High student per lecturer ratios.* In 2014 in the authors' institute, for example, there were 1700 students and 12 professors, that is 142 students per professor (IfI 2014). Rises of enrolment figures in tertiary education have been observed in most developed countries (Mulryan-Kyne 2010).
- *Large class sizes in introductory courses* (Mulryan-Kyne 2010). At the authors' institute, introductory course audiences of 300 to 800 students are frequent.
- *Preeminence of frontal (or* lecturers-*centered) instruction.* Frontal instruction is accepted (by students and lecturers alike) as a necessity in presence of high enrolment figures (Mulryan-Kyne 2010) and as a convenient mean for filtering out "unfit students".[i]

- *Passive student audiences.* Most students taught in large classes are reluctant to ask or answer questions and to solve exercises, especially during classes (Mulryan-Kyne 2010).
- *Tight state control of teaching and examinations.* The authors' teaching is for example subject to ministerial regulations forbidding the use of social media.[ii]
- *Rare, incomplete, and unpublished assessments of learning and teaching performances.*

2.2 Accelerated pace of teaching

The Bologna Process,[iii] a reform of higher education initiated in 1999 and implemented in the following decade in Europe, has tried to significantly increase the pace of learning in Europe's higher education: Curricula must now be "gone through" in about 30% less time than before the reform.

This has led to both reducing the content taught and increasing the pace of teaching. The pace of learning of the majority of students, however, has not increased accordingly (Metzger and Schulmeister 2010).

2.3 Changes among students

Other challenges are changes of the students' behavior since about 2005. As other higher education lecturers (Biggs and Tang 2011, Roehling et al. 2011), the authors noticed among their students widespread reduced attention span, reduced patience, raised expectation of immediate feedback and of immediate applications of newly acquired knowledge, a raised tendency to examination-oriented learning, a raised tendency to collect learning material as a substitute to learning, and a raised distraction during classes caused by on-line media (emails, social media, newspapers). The article (Gehlen-Baum et al. 2014) reports on students' distraction by social media during lectures.

It would be interesting to investigate the causes of these changes. Possible causes are the Bologna Process, the shortening by one year of secondary education in most German federal states (including the state of Bavaria where the authors' university is located), and the almost constant access to social media and electronic communication, students now have grown up with. The rise of examination-oriented learning might be a form of societal impatience and of striving for professional success.

The following societal changes probably favor, if not cause, the aforementioned changes. First of all, courses are no longer the primary source of information for students. Whatever the subject of a Mathematics or Computing Science course, there is an overwhelming quantity of high quality material on the course's subject freely available on the Web.[iv] Computer Science students do access this material and this has significant consequences on their learning for two reasons. Firstly, more than ever before students tend to collect learning materials as a substitute to learning. Secondly, not all of the material they collect for a course is relevant to that course. Indeed, many students, especially beginners, tend to collect advanced material they cannot yet fully understand. Because of the constant availability of online media students now face much more distraction than ever before through on-line media during classes while learning on their own (Gehlen-Baum et al. 2014).

2.4 Choice of instruction methods

For lecturers, the choice of instruction methods turns out to be surprisingly difficult. A first reason for this is a puzzling aspect of higher education: Many higher education institutions are homes to pedagogical research, yet the outcomes of this research are scarcely used, if at all, by higher education lecturers. As far as Mathematics, Natural Sciences and Engineering are concerned, a second reason might be that the discourse in these fields departs from the discourse in Humanities and Social Sciences in a manner that has not been considered so far in pedagogical theories.

All scientific fields are imagined realities, that is intellectual constructions the learning of which is based upon and requires the mastering of specific languages consisting of concepts and of specific manners to articulate these concepts. An essential difference between Humanities and Social Sciences[v] on the one hand and Mathematics, Natural Sciences and Engineering on the other hand, is that the discourses of the former are in natural languages while the discourses of the latter heavily rely on formal languages such as the elementary arithmetic taught at primary schools and programming languages. Formal languages differ from natural languages as follows:[vi]

- *Formal languages preclude analogies and metaphors* while analogies and metaphors are typical of natural languages.
- *Formal languages give rise to short written expressions conveying more meaning than most natural language expressions of similar lengths.* Some twenty symbols long mathematical expressions are more difficult to understand than many two hundred characters long sentences in a natural language.
- *Formal languages are almost always written, even when they are spoken.* Understanding expressions of formal languages that are only spoken is possible but so error-prone that it is almost never done.
- *A discourse in formal languages is intertwined with a discourse in natural language.* A mathematical proof is for example conveyed both in the formal language of the proof's field and in a natural language. Learning how to correctly combine both languages is one of the challenges of higher education.

It takes much time and effort for students to master the formal language of a Mathematics-related field. Most of the authors' students for example need significantly more time to correctly express themselves in the so-called naïve set theory (Halmos 2012), an informal version of the axiomatic set theory, than to express sophisticated thoughts on social media ethics even though naïve set theory is undoubtedly simpler than social media ethics.[vii] Therefore, for beginner's courses in Mathematics-related fields, a teaching form demonstrating correct uses of formal languages is necessary.

Pedagogical methods based on students' discourses anticipating lecturers' complements, corrections, or orientation as proposed among others in Piaget's Constructivism (Griffiths and Guile 2003, Harasim 2012) and Cognitivism (Mandler 2002, Harasim 2012) appear inappropriate in presence of formal languages. If correct uses of formal languages are to be learned, then it is preferable that students express themselves in written form by referring to written teaching materials. Furthermore, there is evidence that guided discovery is more effective than pure, or unguided, discovery in helping students learn and transfer (Mayer 2004).

The need for written expression and for guidance while learning formal languages suggests using a social medium,[viii] giving students the possibility to express themselves on lectures' contents by annotating lectures' slides.

As some authors have pointed out, teaching by lectures can be very effective when it is necessary to introduce a topic before the students read about it on their own or when instructions about tasks must be provided (Mulryan-Kyne 2010). Furthermore, lectures with classroom discussions better promote long term retention, more significantly increase motivation, and better develop thinking skills than lectures without classroom discussions (McKeachie et al. 1987, Angelo and Cross 1993). A social medium is the natural option for enabling classroom discussions within large audiences.

Because of research findings (Di Vesta and Smith 1979, Angelo and Cross 1993, Prince 2004, Yoon et al. 2010) and the experiences of successful lecturers (Chickering and Gamson 1987, Ezzedeen 2008), it seems appropriate to alternate lecturing sessions with sessions during which the learners express themselves by solving exercises or asking questions. Such an approach to teaching is, however, hardly possible with audiences of more than twenty students. The challenge is therefore to lift an intertwining of frontal teaching sessions and sessions of students' activity to large audiences, that is audiences of a few ten to a few hundred students. Again, a social medium is the natural option for addressing this challenge.

Peer Instruction (Crouch and Mazur 2001) which replaces lectures with self-learning from textbooks, so-called inverted classrooms (Tucker 2012, Talbert 2014), would have been a natural choice. Indeed, it has been successfully applied in Physics (Crouch and Mazur 2001) and in Computer Science (Simon et al. 2010). Peer Instruction, however, requires a level of activity that, unfortunately, cannot be expected from students not trained, and therefore reluctant to participate actively in classes. Appropriate rooms and class sizes are further practical conditions for the use of Peer Instruction that cannot be expected everywhere.

3 Didactic approach

A first hypothesis was that a social medium can support large-class teaching by restoring behaviors, especially communication, that are usual in small classes and beneficial to learning. Indeed, a salient property of social media is their enabling of communication within crowds between people who would hardly communicate without social media.

A second hypothesis was that a renewal of large-class teaching is possible that would, if not change the aforementioned problematic passivity of many students, at least be better adapted to most students.

The following goals were formulated:

- to overcome many of the problems inherent to large-class education by
  - inciting students to communicate among themselves (Sandstrom and Rawn 2015) and ask questions, making it easier for them to speak out (Klionsky, 1999, Roehling et al. 2011), and promoting social norms supportive of question asking during lectures (Yoon et al. 2010),
  - eliciting individual as well as group behaviors favorable to learning,
  - promoting Active Learning (Bonwell and Eison 1999, Prince 2004) during lectures;

- to exploit the opportunities that large classes offer (Klionsky 1999, Wolfram 2002):
  - diversity of backgrounds and of approaches to problem solving,
  - an upper level student community sufficiently large for influencing the other students,
  - crowd effects –such as sharing and competing– favorable to learning;

- to address the aforementioned changes in the students' behavior (Roehling et al. 2011) by

- motivating students and re-activating their attention by providing immediate feedback (Chickering and Gamson 1987) and by demonstrating immediate applications of newly conveyed knowledge,
- bringing the content taught in perspective so as to help the learners to recognize and therefore avoid irrelevant learning material,
- occupying the learners computers' and mobile devices' screens so as to fight distraction through online media (Gehlen-Baum et al. 2014),
- and exploiting for a better learning the students' tendency to examination-oriented learning by featuring mock examinations during lectures.

3.1 Large-class teaching renewed

The didactic experiment had to take place under the usual frameworks, such as time, number of students per lecturer, room, and room equipment. These constraints imposed to maintain for each course a weekly large-class lecture (with an audience of 350+) of three hours accompanied by several weekly tutorials of two hours (each with audiences of up to 25).

The contents of the lectures were redesigned so as to explicitly include motivations, the demarcation of similar but differing topics, practical demonstrations (mostly by means of small examples of programming or problem solving).

One to two of the weekly time slots were assigned to self-corrected mock examinations which run as follows: After the completion of a mock examination, solutions were presented and explained by the lecturers. Then the examinations' rating scheme was explained and the students were given the opportunity to apply it for a self-rating. Using the social medium, the self-ratings were immediately collected, aggregated, and the aggregated ratings were presented to the learners (as number of student per possible rating). The lecturers finally briefly discussed the audience's performance and invited the audience to comment on the mock examination.

Inspired by Instructional Design (Gagné 1985) and Active Learning (Bonwell and Eison 1991, Prince 2004, Mulryan-Kyne-2010), the lecture format was redesigned as follows:

1. A strictly serial style was adopted: Each weekly lecture had an easily recognizable core topic and topics spanning over several lectures were avoided (Ezeedeen 2008); the lectures were sequenced by recalling at each lecture upfront last lecture's summary offering the learners to ask questions on the last lecture's content so as to overcome an initial resistance to asking questions widespread among students (Ezeedeen 2008).
2. A summary of the lecture of the day was given both upfront (immediately after last lecture's contents) and as a conclusion.
3. The key elements of a lecture were arranged in an eye- and ear-catching manner and visual and oral sub-titles were introduced so as to combat distraction and help distracted learners to catch up when they return to the lecture.
4. Information was presented in simple, logical, and sequential patterns and, during the lectures only the strictly necessary content was covered. Hints at additional readings were only given on the course's Web page (which was also used for organizational purposes as well as for further practical information).
5. 20 to 25 minutes of lecturing were followed by quizzes or polls sessions of five to ten minutes (Angelo and Cross 1993). The learners' answers to a quiz or poll were collected on the social medium Backstage and immediately shown to the audience in an aggregated form. The solutions, in case of a quiz, were then presented and explained by the lecturers who finally invited the audience to discuss them and the audience's achievements.

This lecture format has been chosen for making it easier for students to attend lectures and to return to the lecture after short distractions or after longer periods of absence (Gehlen-Baum et al. 2014).

The interleaving of lecturing and quiz sessions has been chosen with regard to the fact that most students loose concentration after about 20 minutes of listening. Quizzes re-activate learners by making them apply, or reflect on, content that has been introduced so far.

3.2 Peer correction and inverted classroom

A tutorial format consisting of peer correction, peer feedback on peer correction, software-based weekly task assignments (of homework proper such as problems or exercises, of peer correction tasks, and of peer correction feedback tasks) and work delivery, and inverted classrooms (Tucker 2012, Talbert 2014) was experimented with.

This tutorial format was chosen out of necessity: It was impossible to assign a sufficient number of lecturers to the running of tutorials in the standard form. This tutorial format turned out to have the following unexpected advantages:

- Peer correction provides a learner with both, social support and social pressure. Indeed, peer correction is a "give and take": A student who does not correct the work of fellow students cannot expect to receive corrections of his own work, and vice versa a student who does not give to fellow students material for correction cannot expect to receive their material for correction.
- Peer correction and peer rating of peer correction contributes to developing reciprocity and cooperation among students what, according to Chickering and Gamson (1987) is beneficial to learning.
- Software-based task assignments sustain active participation because "one does not argue with software", as a student put it.
- An inverted classroom also incites learners to active participation because, as it was run, passive attendance resulted in a canceled tutorial.

3.3 Accepting societal changes

Finally, societal changes were accepted. Issues related to learners' behavior were addressed on a blog[ix] not in classes. Indeed, learners nowadays expect individual discussions and have become less patient than their predecessors with the concerns of others.[x] Blogs reconcile these seemingly contradictory attitudes.

Furthermore, a low attendance at lectures was not criticized provided that a sufficiently large proportion of the students absent from lectures did learn. Not only were this acceptance of absenteeism conveyed on the blog but also the condition put to it.

Interestingly, rude or even aggressive comments on the blog were experienced from time to time. For ethical and pedagogical reasons these comments were not censored. The experience was that the learning behavior of large classes was positively influenced if unsatisfied and critical learners were offered a place outside the class where they could speak out their frustration. A frustrated learner might not learn from the answers a lecturer gives to him on a blog. If a lecturer, however, accepts as well as answers public messages of frustrated learners, he can build up or sustain, collective attitudes and behaviors among most, if not all, learners that will positively affect learning.

4 Related work on technology support of teaching and learning in lectures

A hardware or software system that is used in lectures to facilitate and support student interaction and participation is called a classroom communication system, CCS for short (Beatty 2004). CCSs support various forms of student-to-lecturer and student-to-student interaction with the intention of making interactions in large classes similar to those occurring in small classes (Beatty 2004). In addition to person-to-person communication, CCSs also provide electronic communication channels less prone to social inhibition.

Based on the literature, one can basically distinguish between two types of CCSs: backchannels or backchannel-like systems and audience response systems. Note that backchannels are a specific type of social media.

First introduced in (IT related) academic conferences, free-text computer-mediated communication was used to facilitate exchange of remarks and comments of the audience during a conference talk. Communication media used by audiences during presentations are called (digital) backchannels (Cogdill and Kilborn 2001, Kellogg et al. 2006, Harry et al. 2009, Saunders et al. 2009, Atkinson 2010). The positive reception of backchannels in conferences attracted the attention of educational scientists and lecturers. Apart from chats, social media such as micro-blogging platforms, Twitter in particular, have been used and investigated in educational contexts (Yardi 2006, 2008, Costa et al. 2008, Ebner and Schiefner 2008, Ebner 2009, Ebner et al. 2010, Ebner 2011, Junco et al. 2011, Ebner et al. 2014). Certainly, the brevity of micro-blog messages, which can be quickly read and quickly written makes micro-blogging promising for use during lectures.

Besides mere free-text communication as provided by Twitter, topic-oriented computer-mediated communication among students has been investigated. For example, several CCSs or social media aim at supporting collaborative note taking of students (Anderson et al. 2003, Nokelainen et al. 2003, Kam et al. 2005, Nokelainen et al. 2005, Wilkerson et al. 2005). As Nokelainen et al. (2005) point out, students' notes often contain ideas and remarks that can also be of value to other students; however student notes as valuable learning resources usually remain untapped. Individual note taking is perhaps the most frequently exercised learning-related activity of students during a lecture. For a review on note taking, see Hartley and Davies (1978). Using backchannels and shared note taking platforms makes it possible to open up lectures to social and collaborative learning.

Backchannels can also conduce to student question asking in large classes where face-to-face interactions are hardly possible (Rocca 2010). Supporting question asking of students is sensible since questions can be a valuable learning and teaching resource for both, students and lecturers: Students can gain awareness of how peers get along with, and approach, topics; lecturers can receive instant feedback on their teaching and detect, and thus address, fallacies. For a review on student question asking, see (Chin and Osborne 2008).

Apart from backchannels supporting students' question asking, so-called audience response systems, or ARSs for short, have been used to support lecturers' question asking (Fies and Marshall 2006, Caldwell 2007, Kay and LeSage 2009, Lantz 2010, Ebner et al. 2014). ARSs allow lecturers to pose questions (commonly referred to as quizzes) to their audiences and electronically collect and aggregate the students' answers in real time. Students can (usually anonymously) submit answers to these questions. When a quiz is stopped, a summary is immediately compiled and displayed (often as charts) for further discussion and clarification. Although the approach might seem simplistic, ARS support several elaborate teaching models such as Active Learning (Bonwell and Eison 1999, Prince 2004), Peer Instruction (Mazur 1997, 2009, Crouch and Mazur 2001), and the question cycle presented by Beatty et al. (2006). ARSs also make possible a variety of useful interventions in traditional lecture settings (Draper and Brown 2004).

In the past, audience response systems required specific hardware. Recently, Internet connectivity in lecture halls has given rise to Web-based ARSs, many of which are provided as services requiring no software installation (Reinhardt et al. 2012, Ebner et al. 2014, Haintz et al. 2014).

5 The classroom communication system Backstage

Backstage[xi] has been designed to support the teaching and learning activities described in the previous sections. Backstage's design has essentially been driven by the following goals:

- to scale up student-lecturer interactions typical of small groups to large lecture audiences,
- to support frequent and immediate feedback to students and lecturers,
- to provide an additional (and anonymous) communication channel for student question asking,
- to support note taking as a form of interaction and collaboration among students,
- to abridge classroom learning and homework.

Backstage differs from most other CCSs in that it provides both types of CCSs previously mentioned: a backchannel for (mostly) student-initiated exchange and an audience response system for lecturer-initiated exchange. To incentivize lecture-centered communication all messages on Backstage are related to the presentation slides of a lecture.

Backstage departs from most social media in one essential aspect: Instead of drawing the attention of its users to new contents and instead of fostering new relationships and more communication, Backstage focuses communication on the contents of the lecture and fosters a social regulation of the backchannel communication (Baumgart et al. 2012, Bry and Pohl 2014). This specificity of Backstage is the reason for developing a novel communication platform specifically dedicated to teaching and learning instead of using a general purposes social medium.[xii]

The student view of Backstage is shown in Figure 1.

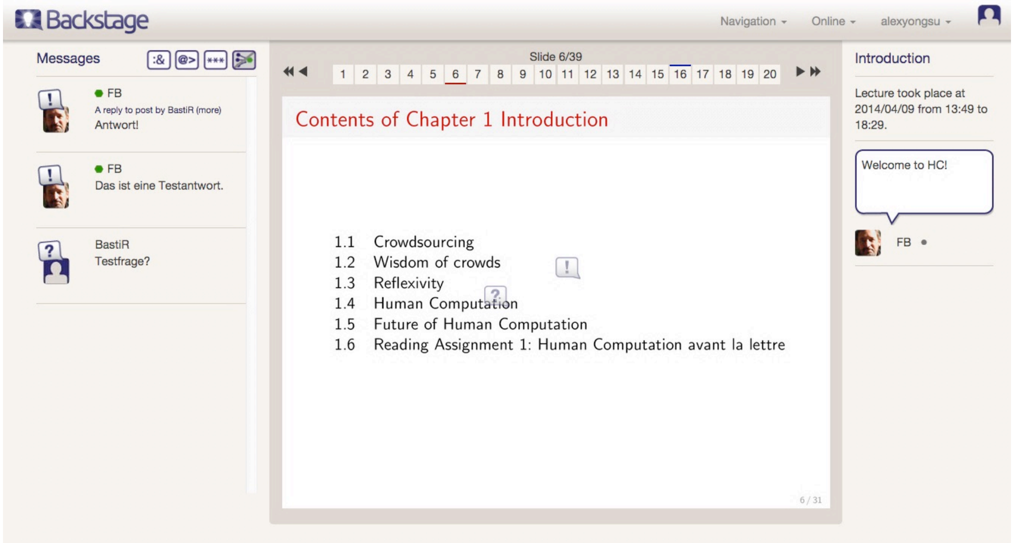

Figure 1: Student's View of Backstage

For posting a message on Backstage, one has first to choose a message type among *question*, *answer*, *comment*, *too fast*, or *too slow* and then to position a message icon on a lecture slide, which gives the message a semantic context.

Backstage fosters social control of the message contents by making it possible for its users to rate a message as *good* (or *relevant to me*, depicted as +), *bad* (or *irrelevant to me*, depicted as –) or *off-topic* (depicted as a coffee mug) – see Figure 2.

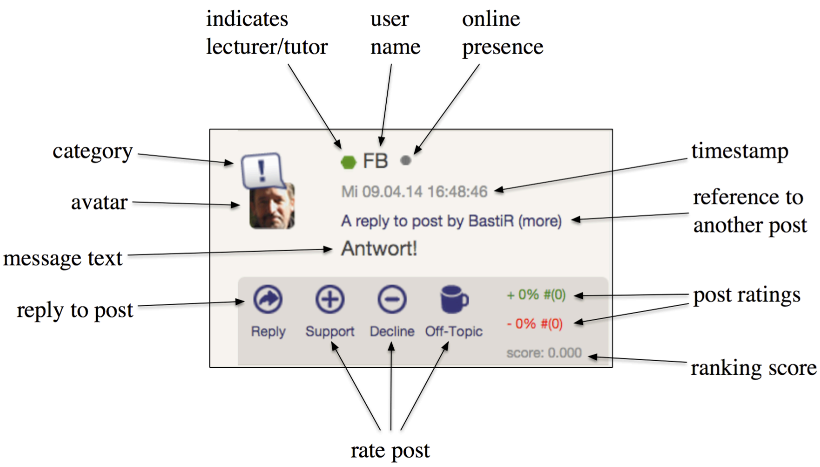

Figure 2: Components of a Backchannel Message

The specific lecturer's role is conveyed on Backstage: A lecturer's messages are marked as such and are therefore easily recognizable (see Figure 2). This feature helps to focus the backchannel communication on the lectures' contents. Indeed, a lecturer marking a message as *off-topic* or pointing to the irrelevancy of a message contributes to keeping the backchannel communication on-topic.

Backstage is designed to be non-invasive: Learners who do not wish to use it, do not have to, and messages are not displayed with the slides on the lecture hall's screen but only on the users' computer screens. Furthermore, Backstage has a concentration mode in which messages are not displayed on a user's screen. Learners can freely activate and deactivate Backstage's concentration mode. Admittedly, lecturers have less freedom. Indeed, a meaningful use of Backstage requires from lecturers to keep an eye on messages posted during or after lectures. For lecturers, this is both, a burden and a boon. It is a burden because it is easier to lecture without caring about questions and remarks from the audience. It is a boon for lecturers caring about their audience's feedback. Furthermore, reading messages during lectures cause short breaks (typically of about three minutes) that improve the lecturing quality (Prince 2004) and learning (Di Vesta and Smith 1979): Indeed, most lecturers tend either not to make short breaks at all or to keep such breaks much too short (typically up to one minute).

Backstage provides a temporal ranking of messages to help lecturers "stay tuned" with the backchannel. That is, a lecturer can choose to filter the backchannel messages according to the best-rated messages providing a form of social regulation: By rating messages, a lecture audience can steer the lecturer's attention to what the audience as a whole considers to be important. Furthermore, message authors are incited to express themselves well so as to increase the chances that their comments receive sufficient support from the audience.

Backstage sustains among its users an awareness of the learners community by displaying the numbers of online learners and a few figures on the Backchannel activity and by providing, at the end of each lecture session, summaries on the quiz-related activity (Pohl et al. 2012).

Backstage is a Web application that can be used with any recent Web browsers. No software installation is required. This makes Backstage easy to use on all kinds of mobile computers. Backstage's audience response system (see Figure 3) can be used on smartphones. Backstage's focusing on the lecture slides, however, makes it difficult to post messages from small screen devices where slides usually are not well readable.

More details about Backstage can be found in Pohl (2015).

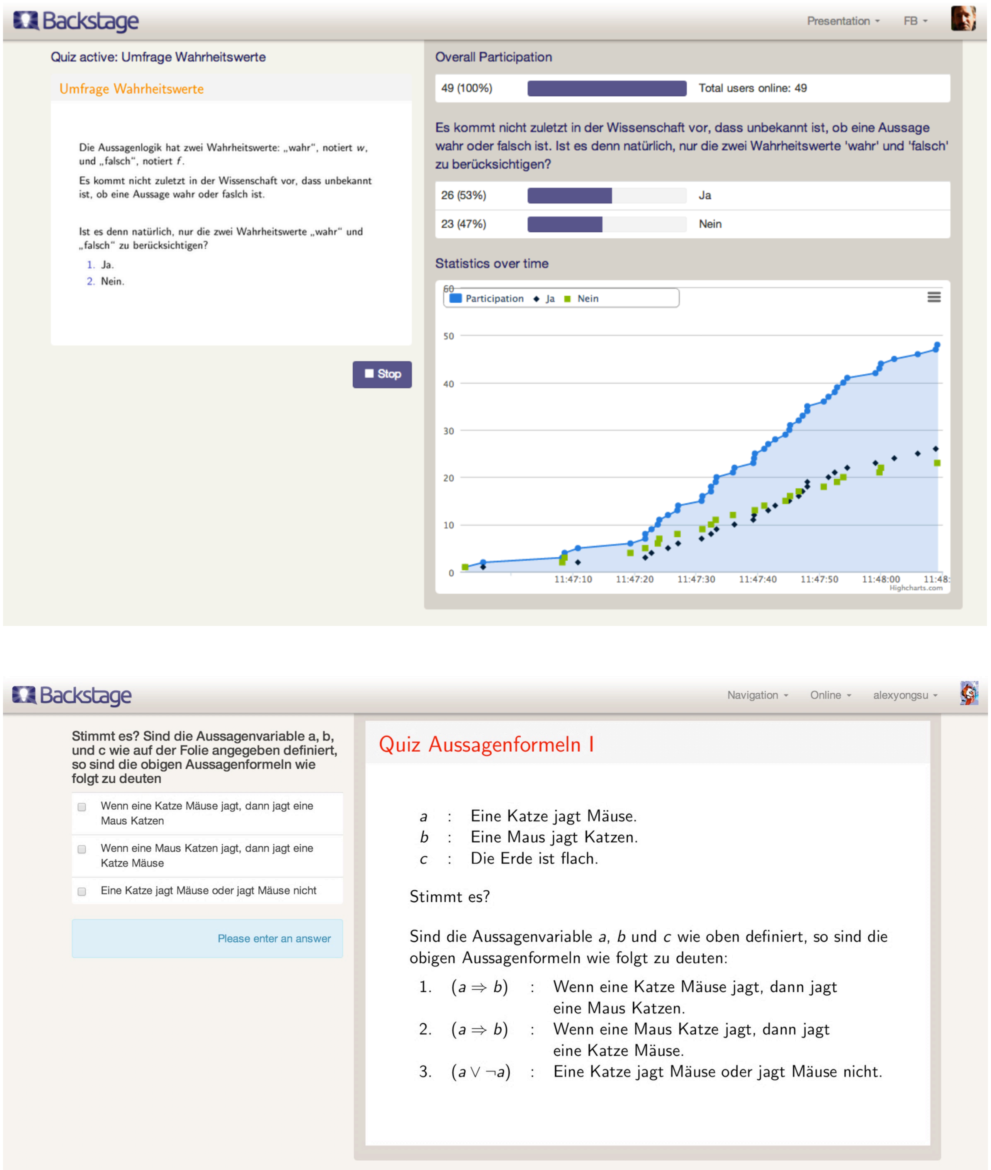

Figure 3: A Running Quiz on Backstage (top: the lecturer's view, bottom: the student's view)

6 Using Backstage in two university courses: A case study

A case study has been carried out in two courses given by different lecturers at different universities with the objective of determining whether Backstage fosters interactivity and awareness in large-class lectures. This case study was focused on the following questions:

- How do students use Backstage?
- Do students appreciate using Backstage?
- Does Backstage distract students from the lecture?

The first question addresses whether Backstage makes it possible for students to express themselves in large classes. The second question addresses how users subjectively perceive Backstage. The third question addresses the following widespread fear among lecturers:

Offering students the use of social media for learning during lectures might incite them to use during lectures other media that are irrelevant to learning.

6.1 Description of the teaching and learning environment

The use of Backstage was analysed in the following two courses:

- LDS: Logic and Discrete Mathematics (in German "Logik und diskrete Strukturen" hence the acronym), Ludwig-Maximilian University of Munich, Summer term 2014
- P1: Introduction to Programming 1, Saarland University, Winter term 2014/2015

LDS was taught using both Backstage and the teaching format described above in Section 3. P1 was taught using Backstage and a conventional teaching format.

6.1.1 LDS

LDS was taught as described in Section 3: The material of LDS was reorganized in such a manner that each lecture presented and completed a self-contained topic; distinct slides were presented at the beginning of each lecture inviting students to post initial comments or questions that should be dealt with before the topic of the lecture was introduced; issues related to learners' behavior were addressed on the lecturer's blog, not in classes.

Students could post messages on Backstage at any time during as well as after lectures. The lecture slides were available for download only on Backstage. The students were not particularly instructed in how to use Backstage but could access from Backstage a one-page-long short comics describing Backstage's principle.[xiii] Quizzes were run on Backstage after lecturing sessions of 20 to 30 minutes.

Two weekly lectures were used for mock examinations during which students had 60 minutes for solving examination-like problems. Upon completion, sample solutions were presented. Finally, the students were asked to grade their own examination solutions anonymously (via Backstage's audience response system) using a comprehensible grading scheme similar to that of a real examination. The aggregated mock examination grades were immediately presented to the audience (as charts) and discussed in the lecture orally and on the backchannel.

The lectures took place every week and lasted three hours, each with a five to ten minutes break at mid time. During the lectures, slides were presented. Occasionally, a chalkboard was used for demonstration purposes. The lecturer was available at fixed times outside the lectures to clarify statements or answer student questions on Backstage's backchannel.

At the end of the course, the students were invited to take part in an online survey on the students' use of Backstage and the (perceived) usefulness of Backstage for increasing interactivity in the lectures and for supporting a better learning.

6.1.2 P1

The lectures were held in a traditional teaching form. Beside the addition of quizzes, the course had not been redesigned in any manner for the experiment. The students were not particularly instructed in how to use Backstage, but they were provided with a help page containing a series of short screencasts explaining Backstage's functionalities. Students could post messages on the backchannel at any time during the lectures. Questions posted on the backchannel were answered orally by the lecturer as well as on the backchannel by a teaching assistant.

In contrast to LDS, in P1 Backstage was used only during lectures. P1's lecturer disabled Backstage's commenting function immediately after lectures: Comments could only be posted on the backchannel during lectures. A content management system and a forum were used for the exchange between students and the teaching team outside lectures.

The lectures took place twice a week and each lecture lasted two hours. They were given by presenting slides. Two additional beamers were used for displaying slides of previous lectures for repetition as well as in-class programming demos. Additional examples, proofs and explanations were provided on a whiteboard.

At the end of the course, students were asked to participate in an online survey, a shortened version of the survey used at the end of LDS.

6.2 Statistical analysis

The evaluation is based on a quantitative analysis of the data collected on Backstage and on a qualititative analysis of the survey responses collected at the end of the two courses.

Since most of the data collected on Backstage is not normally distributed, non-parametric statistical tests were used in the analysis:

- The median (abbreviated Mdn in the following) was used as the central tendency.
- the median absolute deviation (abbreviated MAD in the following) was used as a measure of spread.
- Kruskal-Wallis tests were used for the significance analysis.

6.3 Participants

6.3.1 LDS

In LDS, a total of 269 students registered on Backstage, including students who merely wanted to get access to the lecture slides (only available on Backstage) but neither regularly attended the lectures nor used Backstage.

During the 13 LDS lectures, a median value of 65 students logged in to Backstage (MAD = 16.31, Min = 34 in the last lecture, Max = 91 in the second lecture, see Figure 4).

The lecturer participated on the backchannel, mostly to answer student questions.

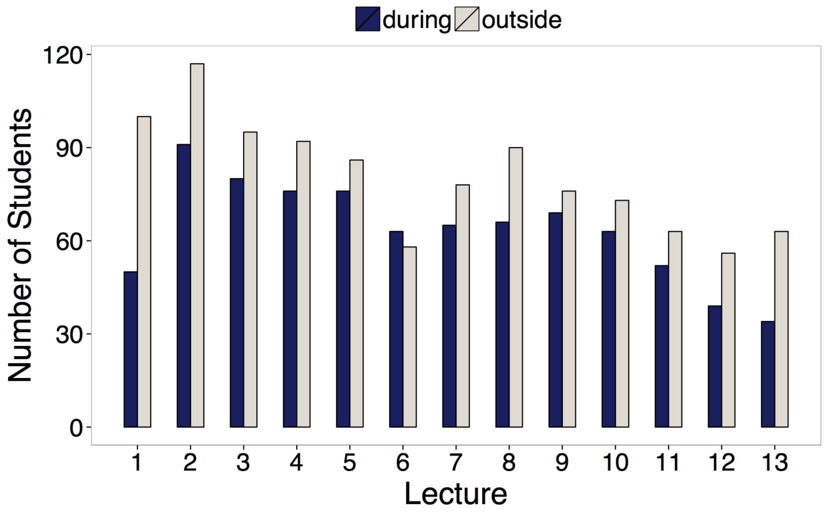

Figure 4: Number of students' logins during and outside the LDS lectures

6.3.2 P1

In P1, a total of 650 students registered on Backstage.

During the 29 P1 lectures, a median value of 141 students logged in to Backstage (MAD = 65.23, Min = 88 in the last lecture, Max = 290 in the second lecture, see Figure 5).

The lecturer and a teaching assistant participated on the backchannel. While the lecturer mostly answered orally questions posed on the backchannel, the teaching assistant participated in the backchannel communication.

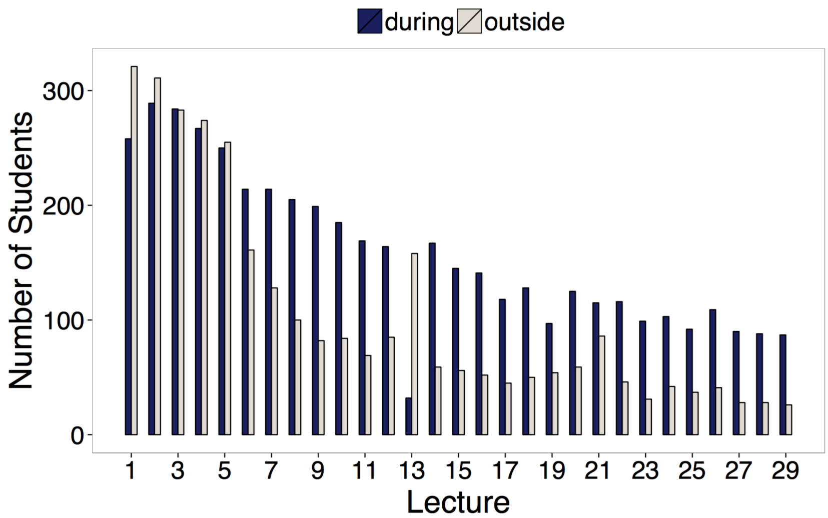

Figure 5: Number of students' logins during and outside of the P1 lectures

6.4 Analysis of the backchannel messages

Two raters independently classified the backchannel messages of the two courses according to the classification scheme of Table 1, which is an adaptation of Cogdill and Kilborn (2001, pp. 10-

11) taking into account the educational context (in particular, organizational messages are considered).

co Content-oriented	Messages referring to the lecture's contents (as presented on slides or on the whiteboard or discussed in the lecture hall through oral questions/answers).
o Organizational	Messages referring to organizational issues (e.g. deadlines for homework, how to download the lecture slides)
po Process-oriented	Messages referring to the lecturer's presentation (e.g. pace of lecturing or microphone issues)
pe Participation-enabling	Messages referring to software used during the lecture (e.g. questions on how to use Backstage)
i Independent	Messages not belonging to any of the above categories (e.g. off-topic messages)

Table 1: Classification of backchannel messages

The codings yielded κ–coefficients greater than 0.84 (LDS: $\kappa = 0.89$, P1: $\kappa = 0.96$), which reflects a very good to excellent agreement between the two raters (Bortz and Döring 2009).

6.5 Analysis of the surveys

The surveys answered by LDS and P1 students included both Likert-scale items and optional open items. A Likert scale was used ranging from one point for "strong disagreement" to six points for "strong agreement". By having to choose a value among an even number of grades, the respondents had to express some tendency and could not remain neutral.

The surveys included groups of Likert-scale items aiming at measuring the following three aspects:

- *interactivity* measured by items such as "I liked posting messages on the backchannel" or "I liked participating in the quizzes",
- *awareness* measured by items such as "I used Backstage to see the other students' questions",
- *revision* measured by items such as "The backchannel exchange was useful for revising the lecture".

In a more extensive evaluation of Backstage reported to by Pohl (2015) of four courses, including LDS and P1, the reliability coefficients given in **Fehler! Verweisquelle konnte nicht gefunden werden.** were obtained. They show that the survey items were convenient at investigating the three constructs interactivity, awareness, and revision.

Construct	α	Description
interactivity	0.84	usefulness of Backstage for promoting interactivity in lecture

awareness	0.84	usefulness of Backstage for gathering learning-related awareness
revision	0.95	usefulness of Backstage for revising lectures

Table 2: Aspects investigated with the surveys

The surveys also included open items such as "I particularly like about Backstage that..." triggering students to express opinions on the functionalities and the use of Backstage. Answering these open items was optional. As a consequence, the respondents' opinions were not systematically collected.

6.6 Results and discussion

6.6.1 The Backchannel communication was lecture-focused in LDS

The numbers and the types of messages posted on the backchannel and the student participation in the quizzes were analysed. The numbers of backchannel messages grouped after the message categories of Table 1 are given in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Types of messages	LDS		P1	
	Mdn (MAD)	Min; Max	Mdn (MAD)	Min; Max
co – Content-oriented	17 (23.72)	0; 63	17 (16.31)	5; 96
i – Independent	4 (4.45)	0; 52	11 (8.90)	0; 72
o – Organizational	0 (0)	0; 3	5 (5.93)	0; 34
pe – Participation-enabling	0 (0)	0; 6	0 (0)	0; 18
po – Process-oriented	0 (0)	0; 2	1 (1.48)	0; 13

Table 3: Distribution of messages in LDS and P1.
The values refer to the number of backchannel messages per lecture.

Kruskal-Wallis tests on the total numbers of messages posted thoroughout the semesters were conducted. Furthermore, Kruskal-Wallis post-hoc pairwise comparisons were applied to investigate differences between the types of messages.

In LDS, significant differences in the types of messages posted by students on Backstage's backchannel were observed (Kruskal-Wallis, $N_{co} = 352$, $N_i = 102$, $N_o = 7$, $N_{po} = 8$, $N_{pe} = 18$, df = 4, H = 12.95, $p < 0.012$, Figure 6). Content-oriented, that is lecture-relevant, communication was predominant (Kruskal-Wallis pairwise comparisons, $N_{co} = 352$, $N_i = 102$, $N_o = 7$, $N_{po} = 8$, $N_{pe} = 18$, all $p < 0.019$).

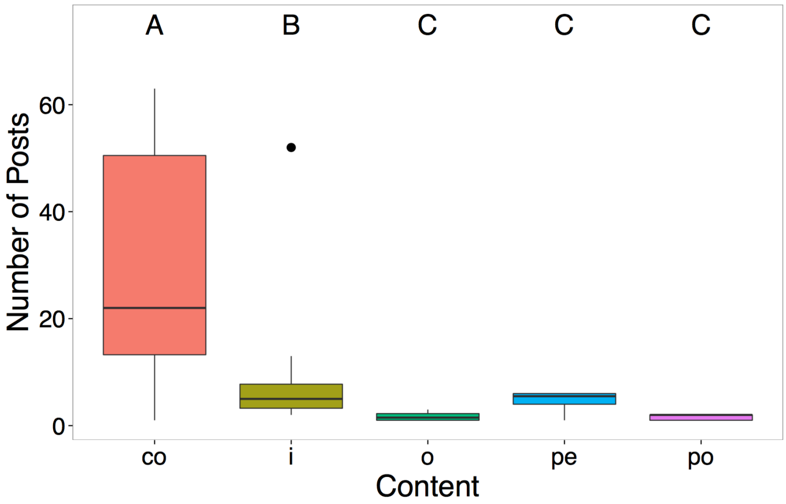

Figure 6: Distribution of messages by type in LDS.
Box-and-whisker-plots with first and third quartiles, median and whiskers (min and max values); values outside 1.5 x IQR are displayed as outliers. Different letters at the top of the boxes indicate significant differences (post-hoc Kruskal-Wallis pairwise comparisons, significance level p = 0.05)

The analysis indicates that almost all backchannel communication in LDS was related to the course's content. The second most frequent kind of messages after content-oriented was independent, which, however, comprised a considerably smaller number of messages than the content-oriented category.

An inspection revealed that most of the independent messages were posted in the first few lectures by students learning to use Backstage. Thus, the independent messages were not a significant disruption during the remaining lectures.

The numbers of organisational, participation-enabling, and process-oriented messages were neglectable in all lectures indicating a strong focus on content-oriented, that is, lecture-relevant messages.

Thus, the use of the backchannel by the students in the lecture LDS can be considered a success.

6.6.2 The backchannel communication was not lecture-focused in P1

Although statistically significant differences in the types of messages posted by P1 students on the backchannel were found (Kruskal-Wallis, $N_{co} = 815$, $N_i = 615$, $N_o = 215$, $N_{po} = 48$, $N_{pe} = 51$, df = 4, H = 82.51, $p < 0.001$, Figure 7), in the course P1 the numbers of content-oriented and independent messages do not significantly differ (post-hoc Kruskal-Wallis comparison, $N_{co} = 815$, $N_i = 615$, df = 1, H = 1.99, $p > 0.158$).

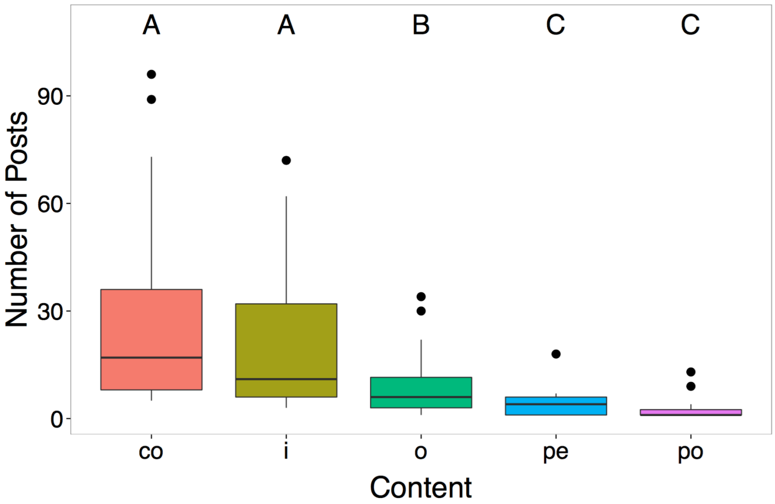

Figure 7: Distribution of messages by type in P1.
Box-and-whisker-plots with first and third quartiles, median and whiskers (min and max values); values outside 1.5 x IQR are displayed as outliers. Different letters at the top of the boxes indicate significant differences (post-hoc Kruskal-Wallis pairwise comparisons, significance level p = 0.05)

A large number of independent messages were posted on the backchannel during the course P1: In P1 contrary to LDS, the backchannel was not used by the students mostly for lecture-relevant communication. The considerable and constant engagement in off-topic communication on the backchannel during P1 has been a disturbance for many students who complained about it. It is unclear why P1 student did misuse the backchannel for disrupting the lectures. This question is dicussed at the end of this section. Interestingly, in no other Backstage-supported lecture, a similar misuse of Backstage's backchannel has been observed.

6.6.3 Most students who were logged in to Backstage answered the quizzes

The median numbers of quiz respondents have been compared with the median numbers of quiz recipients, that is, students who were logged in to Backstage during the quizzes.

In LDS, 60 quizzes were run. A median number of 49 students were logged in to Backstage during the quizzes (MAD = 8.89, Min = 3, Max = 65). A median number of 46 students also participated in the quizzes (MAD = 10.38, Min = 0, Max = 64). This indicates that most LDS students who were logged in to Backstage answered the quizzes.

In P1, 122 quizzes were run. A median number of 142 students were logged in to Backstage during the quizzes (MAD = 65.98, Min = 1, Max = 242). About 114 students participated in the quizzes (MAD = 57.08, Min = 0, Max = 208). Thus, as with LDS students, most P1 students who were logged in to Backstage participated in the quizzes.

The hight participation to quizzes in both courses LDS and P1 suggest that LDS and P1 students appreciated the quizzes.

A high participation in quizzes and an overly positive attitude towards quizzes (as reported about in the following paragraph) are consistent with findings on ARSs reported in the literature (Caldwell 2007, Kay and LeSage 2009, Lantz 2010).

6.6.4 The students appreciated using Backstage

At the end of LDS and P1, the students were invited to answer online surveys on whether they appreciated using Backstage

In LDS, 18 students completed the survey. The responses indicated a good to strong agreement on the usefulness of Backstage to foster interactivity in lectures (*interactivity*; Mdn = 5.42, MAD = 0.62).

Backstage was also found by LDS students to foster awareness (*awareness*; Mdn = 5.30, MAD = 1.04).

Similarly, the responses of LDS students indicate that they found Backstage useful for revising lectures (*revision*; Mdn = 5.12, MAD = 0.93).

In the open items, the LDS survey respondents largely expressed a positive attitude towards using Backstage.[xiv] Among others, the respondents appreciated the functionalities of Backstage, e.g., anonymous communication, and the persistence of comments in written form that helped them in their preparation for the examinations.

The LDS respondents also appreciated the use of Backstage for promoting active participation in the lectures, e.g., helpful feedback by frequent quizzes.

Most of the LDS respondents' criticism about Backstage referred to usability and software stability issues that, alas, can hardly be avoided with a research prototype.[xv]

In P1, a total of 51 students completed the survey. The P1 respondents valued Backstage as a useful means to foster interactivity (*interactivity*; Mdn = 5.33, MAD = 0.49). They also agreed on the usefulness of Backstage to promote awareness (*awareness*; Mdn = 4.80, MAD = 0.89). The P1 respondents, however, were unsure as to the usefulness of Backstage for revising lectures (*revision*; Mdn = 3.75, MAD = 1.11), an opinion that, probably, is a consequence of the fact that in P1 Backstage was used as a technological support during lectures only, whereas other tools were used outside the P1 lectures.

As with LDS, the P1 respondents expressed a positive appreciation of Backstage in the survey's open items. Some P1 respondents expressed for example the view that "Backstage is very appropriate for a first-year course" and "makes lectures more fun".

However, the large number of off-topic messages has been criticized by several P1 respondents. One student stressed that a classroom communication system such as Backstage "requires decent student behavior; otherwise such a system is more distracting than helpful". Other respondents expressed the view that "the possibility of anonymously posting messages contributed to excessive off-topic communication". While this may have been true for P1, we could not find evidence for this hypothesis in LDS and other Backstage-supported courses.

Regarding the use of Backstage by the P1 teaching team, several P1 respondents suggested that the teaching team should be better identifiable on Backstage. This suggestion comes from the fact that the P1 teaching assistant contributing to the backchannel did not register as a member of the teaching team, but as an ordinary student. As a consequence, the assistant's messages were not marked by Backstage as comments of a teaching team member.

In both courses LDS and P1, Backstage was not fundamentally criticized by the respondents, but instead received positive appreciations. The wish for a better, that is, lecture-relevant use of Backstage by peer students has been clearly expressed by P1 respondents. This indicates a need for more guidance and filtering mechanisms on Backstage. Backstage's ARS received much praise from both LDS and P1 students. This is especially interesting, considering that in traditional large-class lectures run without technology support, the introduction of active learning techniques (Bonwell and Eison 1999, Prince 2004) has been shown to negatively affect the students' attitudes about the course (Smith and Cardacciotto 2012).

6.6.4 Backstage did not distract students from the lectures

As described in Section 5, the Backstage's design ensures that students using Backstage during a lecture do not distract students not using it during the same lecture.

For those students intending to use Backstage for learning, the findings above suggest that an excessive off-topic communication on Backstage's backchannel can be distracting. Although similar excessive off-topic communication has not been observed in LDS and in other Backstage-supported courses, the findings in P1 clearly indicate that further mechanisms to prevent distraction are necessary, e.g. personalized filter mechanisms on the backchannel. Several functionalities of the system already address the issue. Yet, more work on distraction prevention on Backstage is desirable.

A comparison by Gehlen-Baum et al. (2014) of Backstage-supported lectures with traditional lectures without technology support reveals that Backstage neither increases nor reduces the distraction caused by lecture-unrelated online activities, such as visiting Facebook or checking e-mails. Interestingly, a sort of synchronizing effect has been observed: Backstage regularly brings back to the lecture students who have been distracted by lecture-unrelated online activities (Gehlen-Baum et al. 2014).

6.6.5 The teaching format probably impacts on how students use Backstage

The reasons why students in P1 engaged in much more independent and thus off-topic communication than in LDS is an interesting question.

A possible reason could be the size of the audience. The audience of P1 was more than twice as large as that of LDS. Individual misbehaviour might be a further reason.

Another reason could be that the teaching format of LDS, unlike that of P1, had been adapted to the use of Backstage. A further investigation revealed that P1 students who engaged in off-topic communication also engaged in well appreciated[xvi] content-oriented communication (Pohl 2015). Thus, students who participated in excessive off-topic communication in P1 also made valuable contributions on the backchannel.

A possible explanation for the differences in the student behavior on the backchannels in LDS and P1 may be that Backstage was employed differently in the two courses. Possibly, the use of other tools than Backstage –for example, for revision and communication outside lecture hours– may have reduced the value of the backchannel communication for learning and thus promoted misbehavior in P1. Further influences on the student use of the backchannel are likely to be related to audience composition and size, as well as to a lecturer's presence on the backchannel.

6.7 Findings summarized

The case study aimed at answering the following questions:

- How do students use Backstage?
- Do students appreciate using Backstage?
- Does Backstage distract students from the lectures?

These questions have been answered as follows:

- Use of Backstage:

  - The backchannel communication differed in LDS and P1: It was lecture-focused in LDS, not in P1. Further studies are necessary to investigate whether the teaching format, the lecturer's presence on the backchannel and group-related factors influence the student use of Backstage for off-topic communication.
  - In both LDS and P1, most students who were logged in to Backstage answered the quizzes.
- The students appreciated using Backstage.
- In lectures in which Backstage has been properly used, Backstage did not introduce further distraction of students.

7 Conclusion

This article has reported on the design and on the use of a classroom communication system, Backstage, for large-class lectures adapted to the teaching practice of higher education Mathematics, Engineering and Natural Sciences. Backstage lifts to large classes the student-lecturer interactions typical of small classes, gives students and lecturers immediate feedback, and abridges classroom learning and homework. Backstage differs from most social media: It does not draw the attention of its users to new contents and fosters neither new relationships nor more communication. Instead, it focuses communication on the lectures' contents by giving semantic contexts to comments and by exploiting social control.

This article has first motivated the use of Backstage in large classes and its original features. Then, it has reported on an evaluation of Backstage's effectiveness in two courses given by different lecturers at different universities.

This evaluation clearly indicates that Backstage can foster among students interactivity and awareness on condition that the teaching format and the lecturer give opportunities for lecture-relevant communication and encourage it. The evaluation has also shown that Backstage and a teaching format conceived to fulfil the aforementioned conditions are received well by the students. Backstage brings back to lectures students distracted by social media; when sensibly used by the lecturers, Backstage is useful for students revising lecture contents and the communication on Backstage is lecture-relevant; and students appreciate using Backstage during lectures and for revisions.

Pamela Hieronymi has compared learning with fitness training and lecturers with trainers while criticizing a widespread too positive attitude towards the MOOC technology (Hieronymi 2012).[xvii] The above evaluation of Backstage suggests extending Hieronymi's comparison as follows: Learning tools, like fitness tools, are as good as their usage; properly used, they achieve their goals, badly used, they do not. Backstage can lift to large classes a working style of small classes favourable to learning, but it is up to the students and lecturers to take the opportunity. The teaching institutions probably must contribute their parts, too, so that such a readiness in turn can deploy its potential: If students are offered a new didactic approach only in a few courses in a while, then it is unlikely that many of them "play the game" when a tool such as Backstage is available (Yoon et al. 2010).

The research reported about in this article is only a first step in a long lasting research endeavour. The findings of this article call for more investigations. The evaluation discussed above was "in the field", a confirmation under controlled conditions is outstanding. The teaching approach described in this article is based on a widespread teaching practice and on hypotheses on learning the formal languages of Mathematics, Engineering and Natural Sciences. To the best of the authors' knowledge, these hypotheses have so far never been explicitly formulated nor scientifically investigated. Such an investigation is outstanding, too. While it is satisfying to know that under certain conditions, Backstage fosters interactivity and awareness, this is not sufficient. Indeed, the ultimate validation of a learning tool is the evidence that it facilitates learning. Such evidence is outstanding. Finally, it would be interesting to investigate whether the described approach to teaching and learning based on large-class lectures and on a written discourse, focused on written teaching material, is appropriate and effective not only in Mathematics, Engineering and Natural Sciences, but also in Social Sciences and Humanities.

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[i] The authors do not share this view. Instead, they consider it anti-pedagogical and unethical to stigmatize students, especially beginners, as "unfit".

[ii] The authors chose to interpret this regulation as referring to general purpose social media such as Facebook.

[iii] The "Bologna process" aims at ensuring comparable education standards in Europe, at making it easier for students to move between European higher education institutions, and at ensuring comparable qualifications. It is named after the University of Bologna where the Education Ministers of 29 European countries have signed a so-called "Bologna declaration" in 1999.

[iv] Many Computer Science teachers are proponents of Open Access and, as a consequence, make freely accessible on the Web much of the learning material their produce.

[v] Even though Social Sciences use mathematical methods, their discourse is no mathematical discourse based upon axiomatizations and computations.

[vi] "Natural languages" is the common denomination for languages spoken by humans.

[vii] It is tempting to hypothesize that evolution has wired a "natural language sense" in human brains but for a lack of sufficient time, no "formal language sense" (Dehaene 2011, Greeno 1991). Indeed, while natural languages probably have emerged already 100.000 years ago, mathematics (and formal languages) has arisen at earliest about 12.000 years ago (Nichols 1998). Furthermore, proficiency in elementary mathematics is widespread in developed countries since no more than 150 years.

[viii] Social media or social networks are computer-mediated communication tools for online communities.

[ix] http://pms.ifi.lmu.de/erlebt/, in German.

[x] This impatience might be a consequence of a high teaching pace and of large lecture audiences.

[xi] This comic is accessible from "About Backstage" on Backstage's main page and at http://backstage.pms.ifi.lmu.de.

[xii] Conveniently used, general purposes social media can provide valuable services to teaching, (Ebner et al. 2010).

[xiii] http://backstage.pms.ifi.lmu.de/

[xiv] For details on the surveys and the survey answers see Pohl (2015).

[xv] Since an instable system was a problem only in the course LDS, a poor Internet connectivity at one of the universities is likely to be the cause of the system instability.

[xvi] Ratings of messages given by other students were used as a measurement of appreciation.

[xvii] Pamela Hieronymi refers to an attitude of MOOCs proponents shared by proponents of other learning technologies. While MOOCs are irrelevant to the present article, her criticism of this attitude is.

