This research was presented on the CSEDU 2022 conference. This is the authors version of the work, it is not for redistribution and only for personal use. The definitive version was published in “Proceedings of the 14th International Conference on Computer Supported Education - Volume 1: CSEDU”, p. 389-396, 2022.
https://doi.org/10.5220/0011087700003182

The Future of Higher Education is Social and Personalized! Experience Report and Perspectives

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Keywords: Technology-Enhanced Learning, Peer Review, Automatic Feedback, Student Activation, Learning Analytics, CSCL

Abstract: This position paper is devoted to learning and teaching technologies aimed at alleviating problems and addressing challenges faced by learners or teachers in mass classes. It reports on practical experiments run over the last terms at the Institute for Informatics of Ludwig-Maximilian University of Munich. Furthermore, perspectives for higher education opened by technology are discussed: Digital social learning and/or experimentation spaces and technology-based personalization. It is further argued that such approaches provide specific advantages that are not only desirable for teaching mass classes.

1 INTRODUCTION

Higher education in most countries of continental Europe and other world regions is nowadays characterized by mass classes, that is, courses attended by one to several hundred students. According to the constructivism learning theory and connectivism (Goldie, 2016), learning is an inherently social process. However, social interactions and discussions become rather limited when it comes to mass teaching. Mass classes make frontal lectures a last resort what often results in rather inactive students and high dropout rates. Furthermore, mass classes often limit the feedback that can be provided by teachers and tutors and make the grading of examinations lengthy and therefore challenging. This position paper is devoted to learning and teaching technologies aimed at alleviating the aforementioned problems and addressing the outlined challenge of mass teaching.

This position paper reports on experiences gained at the Institute for Informatics of Ludwig-Maximilian University of Munich, Germany, through deploying both established and novel Technology-Enhanced Learning (TEL) methods to alleviate many disadvantages of mass teaching for students and teachers alike in three dimensions: First, approaches to activate students in mass classes such as learning-specific backchannels and peer teaching; second, approaches to crowdsource teaching tasks such as giving feedback, correction of submitted solutions and supporting tutors for collaborative feedback provisioning; third, automatized feedback provisioning and examination pre-corrections.

Furthermore, this article reports on experiences of applying data science in education investigated at the same institute: Improving learners’ self-regulated learning by nudging them to peer reviews, by reporting on their learning activities, and by predicting the correlations of their examination performances with their learning activities and, finally, detection of systemic errors among learners by human computation and collaboration.

The research questions addressed in this paper are: (1) How to activate students and increase interactitity in mass classes? (2) How can large numbers of students be exploited (e.g., croudsource teaching tasks)? (3) How to (semi)-automate teaching tasks such as feedback provisioning and correcting? and (4) How to nudge students to active learning?

Finally, perspectives for exploiting TEL in higher education are presented. The discussed perspectives are: The need for social learning spaces, personalization and spaces for experimentation and discussions.

The contributions of this position paper are an overview of deployed approaches to tackle the aforementioned challenges and perspectives for TEL-based social and personalized learning in higher education.

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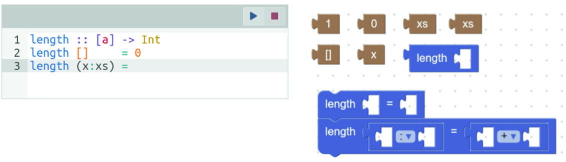
2 ENABLING INTERACTION IN MASS CLASSES

One of the main issues with mass lectures is the limited interactivity. In this section, experiences for two approaches are outlined: (1) learning-specific backchannels from the students to the teacher and (2) TEL approaches to activate students during lectures.

One of the goals for developing the tool Backstage (Gehlen-Baum et al., 2012) was to provide a connected and interacting community dedicated to a single course. The reason for not using existing social media, such as Twitter, was to avoid distraction from off-topic content and to exploit novel learning-specific features. The first version of Backstage offered a digital backchannel to connect lectures' participants (both students and teachers alike). Backstage provided a forum-like structure with which students could ask questions, answer questions of their peers, and comment on the lecture or annotate lecture slides. Posts by students could be up and down voted by the students and teachers as well as categorized by the lecture participants as ”question”, ”answer”, ”remark”, and ”off-topic”. This tagging has shown to be effective at preventing an off-topic use of the backchannel through a social control by the student community itself. Backstage has proven to foster interactivity and awareness in large-class lectures and to encourage lecture-relevant communication in different courses (Bry and Pohl, 2017). Compared to a simple chat such as provided by video-conference systems like Zoom Backstage's backchannel is much more effective at focusing the communication at lecture-relevant contents and at creating social interactions like several students progressively refining a question to a teacher or answering questions posed by fellow students.



```
length :: [a] -> Int
length []     = 0
length (x:xs) =
```

Figure 1: Domain-specific puzzle-like question; taken from (Mader and Bry, 2019a), Fig. 4, p. 213

A second version of Backstage (Mader and Bry, 2019a) has extended the system with an audience response system (ARS) supporting sophisticated quizzes. Backstage's ARS is aimed at activating students within and without lectures. Backstage is a web-based system and can therefore be used by students with their smartphones or mobile computers. Unlike simple ARS, various quiz types are supported, ranging from simple multiple-choice questions over the identification of hot-spots in images (useful for, e.g. medicine education or geography) to domain-specific question types such as creating logic proofs and puzzle-like programming tasks (cf. Figure 1). Furthermore, Backstage's quizzes are adaptive regarding the student's needs and knowledge. Backstage also supports ”phased quizzes” which can run over a longer period of time so as to support self-learning. On the one hand Backstage's quizzes give teachers an immediate feedback on the students' understanding and competencies. On the other hand, they also activate students and give them instant feedback. Backstage, like other ARS in general, have been proven to have positive effects on attendance and engagement (Kay and LeSage, 2009; Oigara and Keengwe, 2013) and can also be used to initiate and foster (offline) peer discussion (Mazur and Somers, 1999) in class.

3 CROWDSOURCING TEACHING TASKS

The main issue with mass teaching is that the number of students is increasing but the number of teachers and tutors cannot be increased accordingly due to limited resources. This directly limits the provisioning of (timely) feedback, which, according to Hattie is one of the most important factors for learning success (Hattie and Timperley, 2007). However, a large class also makes it possible to leverage manpower by crowdsourcing certain teaching tasks.

A first approach to cope with an insufficient number of teachers is peer review. Peer review is a learning activity in which students evaluate and deliver written feedback on the work of their peer students (Nicol, 2010). Peer review and peer feedback is often used in essay writing (Cho and Schunn, 2007), however, it can be used if the tasks to be reviewed require some creativity. Peer review can be operated asynchronously on and as homework, synchronously in class, as a pre-correction for the teacher, or as the final feedback for the students. Peer review and peer feedback have been successfully tested with the systems Backstage (Heller and Bry, 2019b; Mader and Bry, 2019d) and GATE (Strickroth et al., 2011), designed and deployed by the authors in different scenarios such as introductory programming courses (teaching Haskell and Java). The authors' experience with programming assignments is that students good at spotting their peers' errors are also good at identifying correct peers' submissions and therefore are little prone to give false feedback (Heller and Bry, 2019b). However, about 22 % of the given feedback turned out to be partially incorrect – further research on how to support students is necessary. In general, peer review has shown to be a powerful method as it allows students to receive timely and extensive feedback; furthermore, multiple reviews by different peers have been shown to be better than a single review of a expert (Cho and Schunn, 2007). Peer feedback and review also have other advantages that are discussed in Section 5.

Another approach to providing feedback has been tested with a prototype system for reducing the teachers' and tutors' workload for correcting homework (Heller and Bry, 2021). This approach relies on the fact that (1) mass teaching also requires multiple tutors who correct submitted solutions and (2) students often make similar mistakes (e. g., common misconceptions). In order to support teachers, the proposed software uses text processing, collaborative filtering, and teacher collaboration in a wiki-like environment and suggests feedback fragments directly while typing them in. The approach has demonstrated its feasibility and its effectiveness in multiple case studies (Heller and Bry, 2021).

4 AUTOMATED FEEDBACK AND COMPUTER-ASSISTED CORRECTION

Learning requires assessment (Kirkwood and Price, 2008). One can distinguish between assessment for learning (also often referred to as "formative assessment") and assessment of learning (also often referred to as "summative assessment"). In this section experiences with two formative assessment approaches (automated feedback generation and in-class feedback for the teacher) and one summative assessment approach using computer-assisted pre-corrections which both have been tested in two programming courses (in Java and Haskell, respectively) are reported.

Learning requires that students do their homework – regardless of whether the homework is correct or incorrect. In addition, learning is improved by immediate and delayed feedback (Narciss, 2008). Hence, an approach combining both types of feedback has been tested.

It is worth stressing that both immediate and delayed feedback are hardly possible in large classes without the help of technology. For programming tasks, the approach tested consisted of two automated checks that could be requested twice by every student before the final submission deadline. This limitation to two requests aimed at preventing misuses such as gaming-the-system approaches (Baker et al., 2008). The first check was a syntax check using a compiler. The second check was a unit test. A former study with the GATE system has shown that even simple feedback such as knowledge of result/response (Narciss, 2008) (i.e., whether a program compiles or a unit test passed or failed) where each test can be requested by students only once significantly reduced errors in their final submissions (Strickroth et al., 2011). Additionally, the test results were presented to the tutors for each submission as an aid for their manual inspection. This was rated as very helpful by the tutors. In both courses, the correct solutions were discussed in dedicated sessions.

Such automated evaluations can also be used in synchronous settings: A challenge in large classes is the identification of students who need help the most. This is particularly the case in synchronous programming labs: It turns out that it is not sufficient to have a teacher and a few tutors going through the seating rows to help students. A majority of students has questions and expects feedback. Therefore, it often happens that teachers do not recognize, or do not recognize early enough, the most struggling students. To address this issue, a learning analytics dashboard was developed for Backstage that provides teachers with a real-time overview of the progress of all students (Mader and Bry, 2019c). This dashboard allowed the most struggling students to be easily identified by the teacher. The results of a comparative study in which the progress of all students with and without this dashboard were available, are promising (Mader and Bry, 2019c).

Finally, this sections reports on recent experiments to support mass examinations for two different programming courses (with Haskell and Java, respectively). Corrections and gradings should be completed within a specific time frame so that the students can take notice of their performances early enough and, if necessary, can register and learn for a second-chance examination. Traditional paper-and-pen examinations have several drawbacks: First, handwritten text is rarely easy to read. Second, open-ended questions are complicated to grade, and are also prone to lengthy discussions during the inspection of the graded examination – in Germany, students have the right to inspect their graded examination and to raise any objections. Therefore, a fully digital decentralized open-book examination using the GATE system was used. The questions were designed as fill-in-the-gap tasks with one to a few correct solutions or as multiple-choice questions. This also had the side-effect that the examination was more realistic and competency-oriented as the students do not need to program on a sheet of paper with a pen, but can use a compiler and test their solutions. Another design choice was to use a binary marking schema without issuing partial marks. This way the submitted solutions could be evaluated automatically in real-time – this also provided the teachers a real-time view on the progress of the students during the examination. A final human verification of every answer marked by the software as ”probably incorrect” ensured a fair and thorough correction. The automatic pre-correction ensures that only a fraction of the submitted solutions needed to be inspected by the tutors which resulted in a significant reduction of the time needed for the correction. In a first investigation, no significant difference to traditional examinations regarding the pass-failure-rates or achieved grades could be observed.

5 NUDGING STUDENTS TO ACTIVE LEARNING

In this section three approaches to nudging students to actively engage in learning are presented. These go beyond common approaches to nudge students to their homework such as is declaring the homework a condition of participation in an examination or to by grading based on both homework and examination. Both traditional approaches are not always possible due to examination regulations.

Peer review can not only be used to crowdsource teacher tasks (cf. Section 3) but also to provide feedback which improves the learning process by activating students (Li et al., 2019; Zheng et al., 2019). However, an important prerequisite for using peer review is that students actually write feedback and not just try to get feedback from others. A low participation rate poses a significant threat for the entire approach, as students may receive little to no feedback.

A first experiment tested with Backstage in a Bachelor's introductory programming course a low participation rate was observed, however, most students indicated that receiving and delivering peer reviews was “mostly helpful” to their learning and that seeing and thinking about different solutions was remarked positively by the students (Heller and Bry, 2019b).

In a second experiment currently underway using GATE, a restriction was introduced to motivate students to submit their solutions and to deliver feedback regularly (skipping twice results exclusion from further peer feedback). Students' responses to peer feedback are promising: Participation in peer reviewed assignments is higher than participation to assignments which are not peer reviewed. This suggests that reviewing different peers' solutions and receiving feedback from peers probably is a motivating factor to do the assignments. An in-depth analysis of the collected data is underway.

Audience response systems also can not only improve interactivity in class but can also nudge students to actively participate in a lecture and reflect on specific problems. Studies suggest that the use of ARS can lead to higher retention rates and also has positive effects on overall class examination scores, especially for students whose performances are in the lower quartile (Hoyt et al., 2010; Kay and LeSage, 2009). Using Backstage, a team-based social competition with quizzes aimed at boosting participation were tested (Mader and Bry, 2019b). A first evaluation in a small class demonstrated the effectiveness of the approach, and a second evaluation suggests that for use in large classes teams have to be built in a specific way (Mader and Bry, 2019b).

Finally, this sections reports on a case study that uses learning analytics to encourage students not to skip homework and to increase their participation in class (Heller and Bry, 2019a). In a Bachelor course on theoretical computer science, students were given individual predictions of their withdrawal, or “skipping” of assignments, and their examination performances (called ”examination fitness”). The evaluation shows that this course had the lowest skipping rates compared with the same courses over the former three years – for two years the difference is also statistically significant (Heller and Bry, 2019a). Attitudes toward such predictions were also investigated: The students did not find any of the predictions discouraging, nor did they report being motivated to a higher participation to do homework. However, the examination fitness prediction was perceived as more interesting than the skipping prediction.

6 PERSPECTIVES

While TEL is often used to address only pressing classroom organization and management issues (e.g., managing examination registrations and distributing PDF files) (Markova et al., 2017; Henderson et al., 2017), the experience reported in the previous section shows that TEL can also be used to support social aspects of learning, such as computer-supported collaborative learning, co-regulation and peer teaching. In this section the authors present their vision for TEL-based social and personalized learning in higher education that is not only relevant to mass teaching.

6.1 Social Learning Spaces

Good learning, and therefore good teaching, require an intensive, active exchange among students as well as between students and teachers. Such an exchange, however, is what disappears first in mass teaching e. g. when there are hundreds of students in a course. Not all students dare to raise issues or ask questions in front of large audiences. Moreover, it can also be difficult to find learning partners when you sit next to a different student in every lecture.

Social media specialized for learning can be used to create social learning spaces that would be otherwise hardly possible. As described in the previous sections, such systems allow students to ask and, more importantly, structure questions and possible answers. Structuring can also be improved by allowing students to vote for specific questions which they share. This way, the teacher does not have to deal with a dozen questions, but can gain a quick overview and focus on the most urgent ones. Similar approaches could also be used in asynchronous scenarios where students have a shared digital workspace like a wiki where they can collaboratively collect and optimize their questions and answers or provide peer feedback. TEL allows to mitigate the bottleneck in communication.

The last example shows that it is possible to turn mass teaching into an advantage: A large number of students makes it possible to involve them and take advantage of their heterogeneity by forming a community of practice (Wenger et al., 2002). The students have a common goal and can work collaboratively to solve difficult problems. The greater heterogeneity in the group of students is also likely to lead to more questions, and again, collaboration can lead to better questions and to standing up for each other (among others, peer reviews or collaboratively collecting, developing, and optimizing learning materials e. g. in a wiki). Technology also allows students at different locations to collaborate who are not at the same university or even not on the same continent.

The challenge is to design that community and to foster the exchanges – among students and between students and teachers alike – both on the pedagogical and technical sides. Furthermore, there are many more social aspects that can be supported such as how to find other students who share the same interests or are struggling with the same issues.

There are two further issues to address: First, given the speed at which STEM (Science, Technology, Engineering, and Mathematics) is evolving, lifelong learning is becoming increasingly important. Therefore, universities should go beyond alumni portals where graduates have to register manually and create social spaces that allow active exchange with their (former) students to learn and collaborate.

Second, social (learning and collaboration) spaces for teachers are also needed that go beyond a single department, university, or even country. Professional social media can enable teachers with similar interests to connect and share experience as well as collaboratively develop teaching materials (Bothmann et al., 2021; Strickroth et al., 2015). For example, specialized systems and repositories that allow peer reviewing and collaboratively optimizing examination questions should be considered. Such approaches are not possible without the use of technology.

6.2 Personalization

Personalization is probably best achieved by teachers who are in direct contact with their students (cf. previous section). However, such direct interaction is not always possible, e. g., with a students-to-teacher ratio over 800 for professors, and over 70 for teaching assistants (Heller and Bry, 2019b). Here, automation and support through technology can not only free up time that can then be used for more interaction with students, but also provide new insights (on both the small and larger scale) that would hardly be possible without technology.

For learning, students build their own digital personal learning environment with systems provided by the university, such as learning management systems or systems described in the previous sections, and with systems that they selected for specific tasks. Every interaction with these systems such as solving (manual or auto generated) assignments, data traces are generated on the underlying systems. Not only do students generate data when they interact with the systems, but so do teachers when they assess student contributions. This data is often not used systematically, and if it is, it is only used within a single system. The data collected can be useful in two ways:

First, students' submitted solutions, previous attempts and attached meta-data such as marks, grades, or feedback given by teachers can be used for personalization on a small scale: Learning analytics can be applied to the available data in a system to adapt to the needs and knowledge levels of specific students or to aid tutors to give timely feedback. There is a wide spectrum for possible personalization approaches, including generating feedback (e.g., based on similar submissions or shared misconceptions in real-time), generating questions based on the detected misconceptions or knowledge gaps, and using the data of previous venues as a basis for predictions in subsequent venues of courses to warn and support students at risk. Pre-corrections and learning analytics can also be used to support tutors or their collaboration while inspecting student solutions. Additionally, one can analyze how the students interact with the system and with each other, identify usage and learning patterns that can help to adjust the teaching method and to optimize the learning environment including the used software.

Second, students' (life cycle) data such as their participation in exams, their grades in previously attended courses, etc. can be harnessed using data science techniques. On the one hand, this makes it possible to identify students at risk, providing personalized warnings and recommendations for their studies. On the other hand, it can also be used to identify difficult courses and better prepare students for these.

Besides advantages, there are also challenges: Such Learning analytics approaches have only been rarely used in Europe, possibly because of a widespread fear among European higher education teachers to violate privacy regulations. Local university or statewide initiatives are needed to establish trusted learning analytics that engage all stakeholders (cf. (Drachsler and Greller, 2016)). A good starting point could be one study program and then, extend it other study programs and then develop plans on how the data can be exchanged across institutions (e.g., school to university). In addition to privacy, solutions are also needed to avoid possible bias in the data (Riazy and Simbeck, 2019) and to train teachers and students on how to interpret and make use of the analyses (Slade and Prinsloo, 2013).

6.3 Space for Experimenting and Discussions

Finally, spaces for experimenting with innovative approaches to teaching are desirable. This needs to be seen on two different levels:

First, a change in the culture (at least in continental Europe) regarding teaching is needed. Teaching is often not discussed between teachers outside the already interested communities. There are also inhibitions to experimentation, such as data protection regulations that are perceived as too complicated. The COVID-19 pandemic triggered many experiments, however, teachers should not completely fall back to old habits. Rather, teachers should learn from their attempts to deal with teaching in the pandemic and use this as a foundation for further discussion and experimentation. There is an enormous pedagogical potential. Teachers also need to be more creative to think of scenarios that are not or hardly possible without the use of technology such as making use of the heterogeneity of a large class. Again, an exchange between teachers and Technology-Enhanced Learning researchers is necessary to join forces to build up and develop new ideas (cf. Section 6.1). A side effect, or even a specific goal, could be that the technology enables people with disabilities or otherwise time/location-constrained persons such as single parents to take part in courses or learning scenarios.

Second, (flexible) technological infrastructures are needed! This is a rather technical point of view but it is equally important as the first point. On the one hand an infrastructure is required so that also non-tech-savvy teachers can set up and use software that fits their needs in a privacy-conform manner that runs within the university (Strickroth et al., 2021). On the other hand there will be prototypes that evolve over time and show to be effective. A challenge here is to bring these into production and transfer the operating to data centers as researchers cannot operate technology for a whole university (Bußler et al., 2021; Kiy et al., 2017).

7 SUMMARY AND CONCLUSIONS

In practice TEL is often used to address only pressing classroom organization and management issues, however, the experience reported in this position paper shows that TEL can not only be used to support social aspects of learning but can also turn certain aspects of mass teaching into an advantage.

The paper discussed experiences and different approaches for enabling interaction in mass classes, crowdsourcing teaching tasks, automated feedback and computer-assisted correction, and nudging students to active learning. Finally, the paper presents perspectives on digital social learning and/or experimentation spaces and technology-based personalization for higher education opened by technology. The experiments presented in this paper are first steps towards this vision.

The presented results also outline further directions for researching and optimizing the described approaches such as how to better support students in peer reviews on programming assignments. The employed technologies are research prototypes. Limitations and drawbacks are discussed in the respective papers and cannot be presented in detail here due to page limitations.

Almost all studies deal with Computer Science contexts and, therefore, employ domain specific approaches such as unit tests for automatically evaluating programming assignments that are not available in other domains. However, the authors argue that comparable automatic tests can be used in STEM contexts. For other domains such as languages heuristics based on metrics or upcoming machine learning approaches might be applicable as an aid for semi-automated grading or formative feedback (e.g., (Stab and Gurevych, 2017)). Nevertheless, such approaches need to be further investigated. ARS and peer review have already been used in various contexts (e.g., (Keough, 2012; van Popta et al., 2017)).

Most of the approaches described are not limited to mass teaching but can also be used in smaller classes. Here, related disciplines or practices in a school context with about 30 learners are classroom orchestration (cf. (Dillenbourg, 2013)) and learning engineering (cf. (Baker et al., 2021)) which cannot be discussed in detail here due to page limitations. Note, however, that the use of technology should not replace the human component in learning and teaching but should enable or comprehend it. That means that technology can provide timely personalized feedback to students, allow students at different locations to collaborate, enable disabled or time/locations-constrained students to learn and interact with each other, free up time from certain (often recurring and/or tedious) tasks by using automation, or to provide insights into learning processes etc. that are hardly possible otherwise. TEL offers an enormous social and pedagogical potential that needs to be explored...

ACKNOWLEDGEMENTS

The authors are thankful to over 10.000 students who, over the last decade actively participated in testing and discussing the approaches to learning and teaching reported about in this article. The authors are also thankful to their colleagues and (doctoral) students, especially to Dr. Niels Heller and Dr. Sebastian Mader, for their feedback, advice, and contributions to the research reported about in this article. The authors also thank the reviewers for their valuable feedback.

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