3 Years of STACK - An experience report on the implementation and use of formative randomized online tests

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Abstract: We have used STACK in semester-long tests for first-year students, both to reduce procrastination in learning and to provide better support in a mass study program like economics through individualized feedback. Our analysis shows a significant correlation between the results in the tests and exam results. Our results suggest that students appreciate the tests, that they feel better prepared for the exam and would prefer having individualized online tests in all other courses if possible.

Keywords: online tests; individualized feedback; procrastination; learning behaviour.

1   Introduction

Teaching at universities, especially crowded mass courses such as in economics, is characterized by two important developments, digitization and an increasing number of students in higher education. On the one hand, university teaching has changed considerably as a result of digitalization ([GGK19]; [Ka19]; [MMN18]; [Sö17]). There are new possibilities and innovations, some of which compete with conservative teaching methods, but some of which are perfect additions and improvements. But it is not only teaching that is undergoing change. On the other hand, the general learning behaviour of students has also changed as a result of digitization ([Sö17]). Students are now able to learn at any time and any place, as many courses are available digitally. This adapted or changed learning behaviour in turn has an influence on the design and implementation of digital courses by the teachers. They should be adapted as far as possible to the needs of the students ([MMN18]). Furthermore, there are other influences that have an impact on this situation. For example, there has been an increasing urge to study in the last decades as education is becoming more and more important in society and thus many young people are striving for a university degree ([Pe17]; [Au20]). As a result, the number of first-year students has risen rapidly since the turn of the millennium ([St21]). Regarding student composition, there is an increasing heterogeneity. In the area of learning behaviour students tend to learn just last minute, also known as bulimic learning. With regard to

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digital testing we take a look at student's perception, feedback and retrieval practice.

The remainder of this paper is organized as follows. Section 2 describes the current trends and some of the problems that arise in part from these trends. Section 3 contains information about the settings of the course and its participants. It is shown to what extent our course corresponds to the previously explained trends and what preliminary considerations we have made to better adapt our course to the trends and problems. In addition, the exact structure of our project with STACK is described. Section 4 contains some results obtained through the analysis of data and through two voluntary surveys we conducted to evaluate our project. In the conclusion we present three key messages and possible ideas for the future.

2   Current trends and arising problems

The conventional way of teaching at German universities consists of weekly lectures and final exams at the end of each semester. Lectures are regarded as the most common instrument for knowledge transfer ([Sc15]). Sometimes there are corresponding practical exercises or tutorials as well ([Do09]). Students tend to learn more and more online and by themselves ([MG18]).

The digital infrastructure with E-learning approaches, blended learning, online courses, video-lectures on demand or others offers a high flexibility for the students' daily life in terms of location and schedule ([WKK16]; [ND10]). Moreover, students can decide on their own pace of learning ([Go20]; [MMN18]). As a consequence of this digital transformation of teaching, the students' need to visit face-to-face classes in order to receive information and knowledge decreases as all required materials, teaching stuff and much more is available online ([PM20]; [Ay17]; [AH16]). The resulting effect is, that students tend to prefer learning online and by themselves instead of visiting lectures and exercises ([MG18]; [No18]). Nevertheless, traditional teaching is still considered very important ([We18]), but digital content is increasingly demanded by students ([Ti18]).

At German universities, attendance is generally no longer compulsory for most courses ([Hu16]; [We17]; [Ma18]; [PM19]). As a result of this voluntary participation in lectures, it has been observed for a long time in many countries and courses of study that the attendance rates of students in lectures decreases from the first week to the last week of the semester ([Ma01]; [Bo16]; [Ka17]; [Ma18]). This happens although it has often been found and proven that attendance in lectures is positively correlated with success in final exams ([Fa18]; [Ka17]; [BOA18]; [LKS16]; [AS12]; [CL08]; [CRK10]; [FRM01]; [Su17]). In contrast to the decreasing attendance rates, the overall number of students at German universities is rising - 1.41m students in 2009/2010 to 1.77m students in 2019/2020 ([Ho19]; [Bu20]). With regard to teaching and learning in large groups, various problems arise, ranging from poor supervision and overcrowded lecture halls to the perception of the students as merely being an unnoticed part of a large, anonymous crowd ([Ca09]; [Ga13]; [Se16]; [FI15]; [Ol17]).

Another important factor of student's learning behaviour is time management and procrastination. It has been proven that learning contents are much better understood and memorized more lastingly if they are learned over a longer period of time and if they are repeated more often ([CRK10]; [Jä14]; [Hi19]). But actually, students tend to study 'last minute', just before the final exams rather than being continuously occupied with the subject matter throughout the whole semester ([BDR17]; [Ro19]). This is referred to as bulimic learning and means that the content is only learned very shortly before an exam and promptly 'deleted' or rather vomited out of the brain after the exam ([ZSP10]; [Hi19]; [IT17]). However, this approach of unsystematic learning demonstrably leads to worse results and worse memorizing ([Ro19]) as well as to stress and worse grades.

Furthermore, there is an increasing heterogeneity among students regarding different aspects such as socio-demographic characteristics but also educational levels and cognitive preconditions ([Fe18]; [Mo12]; [Zw12]; [HZ15]; [Ha16]). A very heterogeneous group of students is seen as problematic in the literature, especially in mathematics-related courses such as economics ([PM19]; [Ha16]), since heterogeneity significantly increases the urge for individual support, but this is not possible in very large groups due to a lack of resources.

3   Our project

In the following, we present our course, explain our preliminary considerations for adapting teaching to trends and problems and show how our project was concretely implemented with STACK.

3.1   Our Course

In this paper we will focus on the course 'Markets and Firms'. This is a compulsory course for students of the Bachelor of Science in Management and Economics at the Ruhr-University Bochum, to be completed in the first or second semester. Approx. 750 students take the final examination in the winter semester and approx. 200 students take the examination in the summer term. In terms of content, the course teaches basic economic thinking. Students learn how markets work, get to know market failures, learn how market participants make optimal decisions or learn how contract considerations possibly look like.

The structure of the course is as follows. In the winter term there are fourteen lectures conducted by the professor of the chair in every week of the semester. Additionally, we offer ten seminars conducted by research assistants and ten tutorials conducted by students in advanced semesters. In the lectures the content is explained in a more theoretical away with some practical examples. The seminars briefly repeat the important theoretical contents and then mainly deal with applied arithmetic tasks. The tutorials deal with the applied arithmetic tasks in a slightly more step-by-step manner than the seminars. In

addition, the content in the tutorials is dealt more slowly and in smaller groups, so that the target group is mostly students who have not yet fully understood the content.

At the end of the lecture period there is a final examination in the form of a 60-minute written exam. The same procedure applies to the summer semester with the exception that lectures are not held in presence but are only available as video-on-demand recordings.

The organization, the communication with the students as well as the distribution of the teaching materials is handled via the e-learning platform Moodle. Both the lecture notes and the solutions to the exercises and tutorials are made available. In addition to the teaching materials (and the videos), there are also discussion forums.

The attendance rates in the weekly lectures and exercises are decreasing from the first week to the last week (see Table 1). There is still a poor supervision ratio, even though many students only attend lectures and exercises irregularly or do not even attend them at all. We do not know whether this decline is linear or has a different trend, but it has been observed to this extent over several semesters.

	First Week	Last Week	Final exam
Lectures	650	250	
Exercises	300	110	750
Tutorials (max. 35)	35	5	

Tab. 1 – Estimated number of participants in the various courses during a typical winter semester.

We cannot clearly identify the reasons of absence in our case but research suggests that there is no substitution of attendance by self-study ([WR15]; [Su17]). Class attendance and studying the course material outside the lecture halls are complementary ([LB19]). Furthermore, it is shown that the majority of students who miss classes are weaker learners ([Ka17]; [Su17]).

Not only is the course affected by the trend of declining attendance rates, there is also a high level of heterogeneity among students. The course is open university-wide as an elective module, so that approx. 20% of the participants come from other programs and accordingly have different levels of knowledge. Furthermore, the course is of course also subject to the general trend of students to demand more and more digital content. The typical student bulimic learning, also known as student syndrome, is also a predominant topic in our course.

3.2   Preliminary considerations

For these various reasons, we decided to adapt our teaching to these trends and problems. For the adaptation we have made the following preliminary considerations.

Due to the trend of digitalization, it was of course immediately our consideration to also develop something new digitally as an improvement of teaching and to remedy, avoid and prevent the problems mentioned. According to [Qu15] digital content requires a higher

level of self-regulatory skills. Additionally, [So11] explain that the highest learning success of students can be observed when computer-aided teaching and face-to-face teaching is used simultaneously. Therefore, our first preliminary consideration was that our adjustment is not intended to be a substitute for existing teaching components but rather a supplement.

[Qu15] also explains that digital progress can be a response to heterogeneous support needs. That is, with an additional, digital teaching/learning offer, we can do more justice to the problem of great heterogeneity. It is often said that German universities already have a high standard of digitization, but there is also a central shortcoming in this "digitization" and that is the individualization of digitized teaching ([Ha20]). Therefore, our second preliminary consideration is that our adjustment should have the best possible individualization.

Along with this, we must mention that there has been a digital teaching change in the course once. At that time, online tests were developed. However, these only contained non-individualized and non-randomized multiple choice questions. This has obviously led to a major problem, because the concept of online tests in multiple choice format has a blatant disadvantage: it is possibly the easiest format to cheat ([Ga12]; [Ro06]). Thus, our third preliminary consideration is that our adjustment should not only contain (non-randomized) multiple choice questions.

Furthermore, it is said that the learning progress should be continuously assessed and students should receive regular feedback at the best possible rate. And, in order to avoid bulimic learning, the learning control of the students must be such that they are motivated to learn continuously during the semester ([Hi19]). This resulted in the fourth preliminary consideration that our adjustment should therefore be offered continuously throughout the semester and additionally provide feedback.

3.3   Our Design

From these considerations, it quickly became clear that STACK was the perfect tool to improve our teaching and student learning. In the winter semester 2017/2018, we started to develop STACK questions and offered the first three online tests in the last three weeks of the semester before the final exam. After this first attempt, we made a major adjustment to the implementation in the following winter term. Instead of offering three online tests in the last three weeks of the semester, we then offered six online tests in 2018/2019 distributed over the entire semester in accordance with the preliminary considerations. For these six online tests, we always provide a learning plan immediately at the beginning of the semester, so that the students can see what content they need to at least learn beforehand in order to be able to successfully complete the test.

The tests we offer differ greatly in the framework conditions. At the beginning of the semester, students have multiple attempts at the tests and the attempts have no time constraints. This allows us to meet students' needs for digital content with a high degree

of flexibility in their completion. As the semester progresses, the restrictions tighten, i.e., there are fewer attempts per test and the time limits per attempt become stricter. The peak of the restrictions is then found in the last test shortly before the final written exam, when only one attempt is allowed with a tight time limit. In this way, we gradually introduce the students to the exam situation and offer a simulation that is close to the exam.

Another component in our design is needs-based adaptation. We take a look at the first tests in the semester and identify the poorly performed questions and items. These are then asked again in subsequent tests. In this way, we offer students the chance to revise contents they did not fully understand before. We do this because it has been proven that learning content is much better understood and also more persistently remembered when it is learned over a longer period of time and repeated more frequently ([Hi19]; [Jä14]; [CRK10]).

We began another major adjustment during the 2018/2019 winter term. We asked students to handwrite their calculation paths on the online tests and submit them to us. Then, from the submissions, we identified the students with incorrect solutions. From these incorrect solution paths, we then identified the most common errors per task. We implemented the most common errors per task into the feedback trees of the existing STACK questions, allowing us to offer highly individualized error feedback starting the following term (2019/2020). So if a student enters a partial or final result, which is not correct, the feedback tree will now first go through all possible incorrect results for which specific error feedback can be given. If a specific error is found, the student receives the feedback that he/she probably made this error. If no specific error is found, the student is only informed that the result is not correct and, if applicable, what the correct result is and how to achieve it.

For the online tests, students can earn extra credit for the final exam by participating and performing well. A maximum of 10% of the points of the final exam (60p.) can be earned, depending on cumulative performance on all tests in a semester. These extra points are awarded as a participation incentive and are then added on top of the points earned in the exam.

For our project, there are two different approaches for the evaluation and analysis. On the one hand, we have the performance data of all participants of the online tests and the final exams. On the other hand, we have done two voluntary surveys, once in the winter semester 2018/2019 and once in the winter semester 2019/2020. These two surveys had mostly identical items. Table 2 shows the numbers of participants in the tests, in the exams and in the surveys.

	Tests	Exam	Survey
2018/2019	696	768	182
2019/2020	661	702	252

Tab. 2 – Number of participants in the online tests with STACK, in the exams and in the voluntary surveys in both winter terms, 2018/2019 and 2019/2020.

4   Our findings

A first brief analysis we made was to assess the relationship between performance on the online tests and performance on the final exam. To do this, we did a linear regression analysis. For the recent semester (2019/2020) the R^2 is 0.146 and the adjusted R^2 is 0.144. It has to be said that we can only explain a correlation and no causality can be established. For a causality we are missing some more variables and data at this point. Fig. 1 shows the correlation as a scatter plot with a drawn trend line.
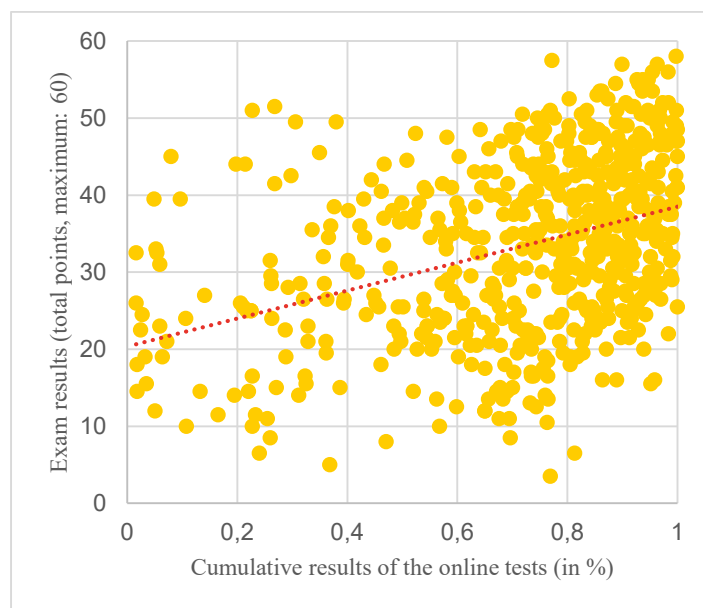

Fig. 1 – Correlation between performance on the online tests and performance on the final exam

In our analysis, of course, we did not consider the extra points. That is, we have related the pure performance during the exam to the performance on the tests. However, by means of the regression analysis it can be said that about 14-15% of the variance in the exam scores can be explained by the performance on online tests.

One very important insight can be derived from our adaptation towards individualized error feedback. The added value of STACK questions becomes significantly higher for students if the errors frequently committed in a task are implemented in the feedback tree and thus individualized error feedback can be issued once any of these errors occur. We used two nearly identical questionnaires within the two voluntary surveys in the 2018/2019 and 2019/2020 semesters. Except for the introduction of the above-mentioned error feedback, the online tests and the structure of the project were also identical in both semesters. The results in the surveys of the two years are almost congruent in all respects. However, it is particularly noticeable that 3 items had significantly better responses in

2019/2020. These three items dealt with individual error feedback. In three items 2.10, 2.11, 2.12, students indicated that the displayed solution helped them find their error, that the displayed solution helped them understand the error, and that the displayed solution helped them learn from the error. How significantly better the answers to these three items were can be seen very well in Fig. 2.
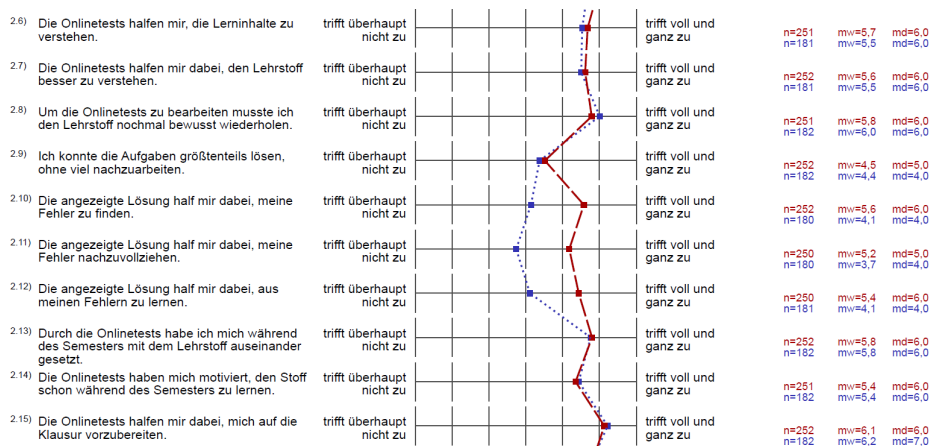

Fig. 2 – Extract from the comparison between the survey in 2018/2019 and 2019/2020

The results of the survey 2019/2020 displays further insights into the benefit of the individualized online tests, if they are distributed over a longer period of time instead of only at the end of each semester. The perception of the online tests is quite positive, as the results of the survey suggest that students would recommend doing these tests to their fellow students (2.25).

	No. 2.1	No. 2.4	No. 2.10	No. 2.11	No. 2.12	No. 2.13	No. 2.14
Valid	252	252	252	250	250	252	251
Missing	2	2	2	4	4	2	3
Mean	6.175	5.698	5.575	5.180	5.436	5.798	5.351
Std. Deviation	1.119	1.270	1.388	1.530	1.408	1.319	1.471
Minimum	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Maximum	7.000	7.000	7.000	7.000	7.000	7.000	7.000

	No. 2.15	No. 2.18	No. 2.20	No. 2.21	No. 2.25	No. 2.26	No. 2.27
Valid	252	247	246	248	246	246	246
Missing	2	7	8	6	8	8	8
Mean	6.131	4.862	5.191	5.944	6.589	5.984	6.427
Std. Deviation	1.185	1.508	1.239	1.297	0.693	1.146	1.085
Minimum	1.000	1.000	1.000	1.000	4.000	1.000	1.000
Maximum	7.000	7.000	7.000	7.000	7.000	7.000	7.000

Fig. 3 – Evaluations from various statements of the 2019/2020 survey

The majority of the students value these online tests as an "important part of the course" (2.1). With regard to the concept of online tests being rather a supplement than a substitute for the whole study experience, our students evaluated the use of online tests to be a "component of different parts that complement each other in the course system" (2.26).

Furthermore, the benefit of these tests become clear when asking about other courses of their study: over 85% of the survey participants stated that these "online tests should be offered in other courses as well". One particular reason could be that students feel well prepared due to the constant confrontation with the course content and tasks related to the exam. In the survey, students stated that the online tests make them "feel better prepared for the exam than in subjects where there are no comparable tests" available (2.21). So, online tests seem to be "an adequate tool to help students prepare for the exam" (2.15) and "to make them feel confident with their preparation for the final exam" (2.20).

Not only that, but students appear to appreciate the use of online tests throughout the semester, because "they enjoyed working on the tests" (2.18), which also help them to be "motivated to study on their own" (2.4). A major problem that we focused on is the phenomenon of so-called bulimic learning, when students tend to procrastinate and have to learn a lot in a short amount of time, just before the exams (quelle). This leads to the effect, that the studied content will be forgotten right after the exam (Quelle). The results of the survey reveal that the option to do the online tests, which were distributed over the whole semester, "encouraged and motivated students to already deal with the content during the semester rather than only towards the end" (2.13 und 2.14).

5   Conclusion

From the evaluations of our project, we can note three key statements. First, the benefit of STACK questions for the students increases significantly by implementing common errors in the feedback trees of the tasks and it is then possible to offer individual error feedback. It should be noted, however, that this is associated with a considerable administrative effort on the part of the teachers. Second, according to our surveys, the design of our project seems to be able to at least partially reduce students' procrastination or bulimic learning. Third, we found that the online tests within our setting can also make students enjoy learning, which might not always be self-evident.

For the future, we would like to collect more data in order to be able to conduct further analyses, such as examining causality between performance in online tests and final exams.

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