Online Self-Assessment in Mathematics at the University of Bern

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Abstract—In the Swiss education system the cantons oversee educational matters, practically meaning there are 26 different school systems. This is also reflected in the graduation exam, which is organized locally in every high school. Based on this assessment and their preference, students are admitted to university without any additional entrance exam. This motivated us to create an online self-assessment. Its two mathematical parts serve a different purpose: one evaluates basic mathematical skills, and the other one deals with abstract reasoning that gives students a flavor of university mathematics. Additionally, the online self-assessment contains a set of metacognition questions regarding motivation, expectations and attitude towards mathematics. Our goal is that students to identify their strengths and help them make a more informed study choice. The technical tool used for the implementation is STACK, an open-source online assessment system in mathematics. Concerning this use case of STACK, we are currently collecting students' feedback. We will present our first conclusions on this matter, which serve as a basis for further adjustments of the material.

Keywords—mathematics education, study choice, online self-assessment, STACK

1 Introduction

Self-assessment is "the evaluation or judgment of 'the worth' of one's performance and the identification of one's strengths and weaknesses with a view to improving one's learning outcomes" [4]. It promotes metacognition of learning and allows students to critically reflect on their abilities, efforts and motivation. These are exactly the aspects that students need to understand when choosing their domain of study. Therefore, we have chosen to provide them with help on this matter by creating a self-assessment.

In accordance with the current digitalization trend in education, we implemented this self-assessment as an online resource using STACK questions [10] with automatic evaluation and feedback, OSA for short [7]. This context provided us with the opportunity to use STACK for more conceptual questions than in our previous project, where we designed algorithmic linear algebra problems.

By making the test available to everyone, we hoped to reach all students who consider studying mathematics, physics or computer science. This represented our target group, because early dropout rates from university are one of the highest for exact and natural sciences. More specifically, for exact and natural sciences, the rate of first year bachelor students graduating at the same university and in the same domain of study as they started in is the lowest [11].

The design of the online self-assessment has already started in 2021. Its structure and purpose were presented at the International Meeting of the STACK Community 2021, and are included in the conference proceedings [5].

As mentioned in [5], the main sources of inspiration for the creation of the OSA are the MINTFIT Hamburg [1] and the online self-assessment of the University of Bonn. These can be accessed via the links [6] and [2], respectively.

2 Description of the online self-assessment

The OSA is implemented as a test composed of 38 STACK questions, organized into the following units (see Figure 1):

Fig. 1. Progress bar of the OSA

1. Demographic questions – "Fragen zur Person," which have a statistical value, providing the profile of future students (like age, where did they graduate, core subjects).
2. The first mathematical part – "Aufgabe 1, Aufgabe 2, Aufgabe 3," questions 2–26, consists of three guided problems. One related to set theory, one about the Cauchy-Bunyakovsky-Schwarz inequality solved using mathematical induction and one about probability theory. These results are classical, but their proofs are presented in a non-standard way. The goal is to check whether the participants can follow a complex process of analytical reasoning.
3. In questions 27–32 – "Vermischte Aufgaben," basic mathematical skills are tested. This part of the quiz is compound of short, independent questions, for which one needs to recall some basic factual knowledge, as well. These questions are grouped into 6 categories: computations, functions, graph of functions, geometry, trigonometry, and logic.
4. The next part – "Erwartungen & Interessen," is about students' expectations, interests, and motivation. We refrain ourselves from evaluating their answers directly as correct or incorrect, and we let them compare their attitude with ours.
5. Starting from question 36 onwards – "Rückmeldung zu OSA," we ask for feedback about the OSA itself. We are interested in finding out how do students evaluate it and whether they would recommend it to their peers.

3 Results

The implementation of the OSA was finished towards the end of 2021. We made it available at the beginning of November. We spread the word about it at the annual Teacher Conference of Canton of Bern in December. By the International Meeting of the STACK Community 2022, 110 people accessed it, out of which 52 spent less than 5 minutes just browsing through it and 11 answered all questions. Out of these 11 one is a colleague of ours and just 10 were students. We are going to present some aspects of the feedback about the OSA restricting ourselves to these 10 students.

3.1 Difficulty of problems

Students were asked to answer the questions "Which tasks did you perform well?" and "Which tasks did you have trouble with?" To provide an answer students could choose which problems to assign to each category. Table 1 summarizes these results. For example, 6 students out of 10 had difficulties with Problem 2 – Induction.

Table 1. Difficulty of questions classified by students

	Which Tasks did You Perform Well?	**Which Tasks did You have Trouble With?**
Problem 1 – Set theory	8	1
Problem 2 – Induction	2	6
Problem 3 – Probability theory	1	5
Basic skills – Computations	8	0
Basic skills – Functions	8	1
Basic skills – Graph of functions	4	3
Basic skills – Geometry	3	1
Basic skills – Trigonometry	2	2
Basic skills – Logic	8	0

We expected that students would find the probability theory problem difficult, and this was confirmed by their feedback and score. An explanation could be that in case of such problems one has to construct a mathematical model based on information given as text. This is a non-standard procedure and students might not be familiar with it. In addition, it does not follow a valid pattern or recipe. Also in Switzerland this is among the last topics covered in high school, so some of the students might not have studied it yet.

Induction is a classical chapter in the mathematical curriculum; thus, we did not expect that this problem would be perceived as complicated by so many students. What might have caused difficulties is that our induction problem, namely the proof of the Cauchy-Bunyakovsky-Schwarz inequality, is again a non-standard one.

In the set theory problem, the computations, functions, and logic parts students performed well. About the other parts (graph of functions, geometry, trigonometry) we received a mixed and balanced feedback. The fact that these problems were chosen

by less students proves that these parts were not perceived as extremely difficult, but students did not perform extremely well on them either.

3.2 Time to completion

Our goal was to create an OSA which takes about 2 hours to solve. We tested this by addressing the question "How much time did you spend for solving the OSA?" The most popular answer was "approximately 2 hours" with 40%, and the rest of the answers were equally split between the two categories "less than 2 hours" and "more than 2 hours". We can conclude that the results match our initial objective.

3.3 Is OSA helpful?

We were aiming to conceive an online self-assessment, that is a decision aid for the choice of study, and which helps students better understand what mathematics is about. 90% of the students confirm that both of our objectives were met.

3.4 Change of interests

One of the most important questions for us was the one reflecting the change of interests, namely how much did the online self-assessment influence students' interest in studying mathematics. For half of the participants the interest did not change. Their prior understanding of mathematics and their expectations already matched our point of view to a great extent. It is a positive aspect, that for 40% the interest in mathematics grew. For 10% the interest in studying mathematics decreased. In this case the online self-assessment confirmed that this is not the right choice of study, as this person also claims later, that they do not want to study mathematics.

3.5 Student input

We asked students what they appreciated about the OSA. We summarize the answers in Table 2. We emphasize three aspects of this matter:

- It was appreciated that a brief introduction to the topics was available, which was especially handy for the students that were not familiar with them.
- Students enjoyed that a variety of topics and competences were covered by concrete and unconventional examples.
- Furthermore, the solutions provided in the feedback proved to be useful for a better understanding of the problems and of one's mistakes.

Table 2. Student input

What Did You Appreciate about the OSA?
"I found it good that you got an introduction to the respective topic first, if you haven't dealt with it at school yet."
"Topics were examined using a concrete example. A concise introduction to the topics was available."
"How the many different fundamental areas required to study mathematics were presented from interesting angles. Good for assessing whether you have the appropriate knowledge and aptitude. The 3 main tasks."
"Many competencies of mathematics are covered by specific tasks."
"One was well guided through the tasks. The solutions provided in the feedback help a lot to understand the problems. This way, I was able to assess well whether I made a careless mistake or whether I had not understood the question yet. Most of the time I understood the tasks well thanks to the solutions."

4 Conclusions

Until now the target group consisted of potential future students, for whom the completion of the OSA was recommended, but not mandatory. The OSA was well received by this audience, but more data is needed to understand what kind of adjustments are in order.

Consequently, from the fall semester 2022 the OSA has been made mandatory for all registered first year students, and the collected data is being processed. For this set-up, our goal is slightly different, namely we would like that students ask themselves the following question: "Before the year starts, in order for my studies to go smoothly, do I need to invest more time into studying mathematics?" We informed the enrolled students about OSA in such a way that they could subscribe to the bridging course offered by our institution before the start of the new academic year.

This state of affairs motivates our current project, namely "Focus on reasoning and proofs," which aims at easing the transition to university level mathematics.

5 Prospects

At our institute it is a well-known fact that first year bachelor students struggle with the transition from school mathematics to scientific university mathematics [8]. This was observed by several professors, who are also participating in the graduation exams as experts.

One of the main reasons for this struggle is that mathematics in school focuses on calculations and problem solving, while at university one carries out reasoning on a more conceptual level. The lack of mathematical argumentation is a universal problem [3], and it is an obstacle in understanding what mathematics is about [9].

The outcome of the aforementioned "Focus on reasoning and proofs" project is an online mathematical module addressed to current and potential future students in mathematics, physics, and computer science. Currently this concerns yearly

250–300 students. The main goal of the module is to introduce the basic proof techniques and to improve proof comprehension. This way our new bachelor students will be able to integrate the new mathematical knowledge easier.

This year we started a collaboration with a learning analytics project. In this framework we plan to use the data collected from OSA to predict the success rate at the major first semester subjects (linear algebra and analysis).

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