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Exam as an instrument for student-active learning in STEM education – An example from a reliability analysis course

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ABSTRACT: Exams have a powerful role in higher education typically in the form of summative assessment, where the goal is to evaluate student learning at the end of the course; to test whether the students have achieved the learning objectives. Beyond representing a final activity in the course, exams have a role in giving students exam-relevant problems to solve, and to communicate a set of standards. It can be argued that this problem-solving activity contributes to learning and will make the students better equipped to perform well on the final exam. From the teacher's perspective, the designing of exams represents a task creating specific awareness to the course content and student capabilities. In this paper, focus is on student activity and in-depth learning, where we investigate a potential to use exams more actively in learning activities prior to the summative assessment. A way suggested in this paper and tested for a reliability analysis (probability and statistics oriented) course, is to have the students design on their own an exam set with solutions, preferably in groups. The students have access to supervision and are given feedback on their product. There is a rationale that this activity may add motivation, and results indicate a positive learning benefit from the initiative, which is also supported by feedback collected from the students in the course evaluation. Main feedback being that it makes them see problems from different perspectives and taking a more active role. Besides, the format to work together with other students on solving a low-stake but value-adding task without direct influence on their grade was appreciated. The way allows for creative thinking and reflection. It extends the traditional use of exams and represents a way in line with problem-based learning thinking.

Keywords: *exam, summative assessment, learning activities, reflection, in-depth learning*

1 INTRODUCTION

A main objective of exams is to assess student performance or 'student quality' against some predefined learning objectives, during or at the end of the course. Particularly, there has been a focus in literature on the summative assessment type (see e.g., Sambell et al. 2012; Burke 2010). Such an assessment represents a final student activity in the course, where they are tested on whether knowledge, skills and competence targets are achieved. The associated grading is then supposed to reflect the level of the student, while also to some extent providing feedback for confirmation and post learning. Where, the quality of the exam relates to the ability to test achievement of the learning objectives, for example by coving a broad spectre and give weight to main parts of the curriculum.

Ideally there is a strong correlation between the exam results and individual in-depth learning. However, as students might be motivated by scoring well on the exam, they might direct focus on activities optimizing the exam performance. This on the expense of in-depth learning. For example, spending less time on project work if this doesn't have a direct influence on the grade. Another example is the prioritization and time spent on solving previous exams, where focus is on how to answer the typical exam problems, and maybe not so much on exploring the depths of the course.

An objective of such an instrument is to examine the level of the student with respect to the targets mentioned above. As such exams, as an instrument to measure 'student quality', links strongly to the student motivation. Beyond representing a final activity in the course, exams can be used during the course to give them exam-relevant problems to solve, and to communicate a set of standards. There is then an expectation that the problem solving contributes to learning and will make the students better

equipped to perform well on the exam. This under assumption of consistency and quality in previous exams.

In literature, and especially in problem-based learning literature, it can be argued that the solving of previous exams has value in building competence. It's an activity covering a broad spectre of learning objectives. This especially when combined with an autonomous course design, an aspect pointed to as important to learning in contemporary motivational theories, e.g., in the self-determination theory (Gagne and Deci 2005; Jeno et al. 2017). Where the students may select which problems to solve depending on their level and ambition.

In problem-based learning and in the self-determination theory, there is focus also on a third element, in addition to competence and autonomy, i.e., relatedness (see Figure 1). Relatedness refers to a learning frame where the students are given the opportunity to work together in developing and solving problems and to reflect on what they do. While the solving of previous exams clearly can be framed as a group activity, ownership to the problems and room for creativity and reflection might still score low. Current exam problems come with an examinator guidance, giving students the solutions if needed. Besides, the variety is obviously restricted to problems given in the past and the quality in these sets. This challenges student-activity and the premise for problem-based learning.

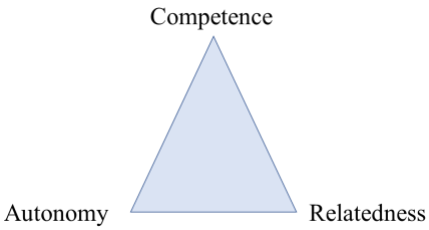

Figure 1 Key student needs in problem-based learning

An alternative, where exams is being used in a more student-active way, is to have the students design full exam sets on their own. The idea is then, that the students in groups work on formulating relevant problems covering the learning objectives in the course. They will also have to produce an examinator guidance giving solutions to the problems. This being a way in favour of relatedness, but also promotes ownership, creativity, and reflection. It extends the traditional use of exams and represents a way in the *spirit* of problem-based learning.

Such a use was tested in a probability and statistics-oriented course given at the University of Stavanger. We refer to Section 2 for further details.

2 METHOD – INITATIVE FOR STUDENT ACTIVE LEARNING

The exam-initiative was tested in a reliability analysis course (10 ECTS). This is a course on master level available to different study programs at the faculty of Science and Technology at the University of Stavanger. The course has around 120 students; and is characterized by an autonomous design where the students can select from a combination of learning activities e.g., reading textbook, attending lectures, watching videos, and work on problems and exams sets.

Half-way into the semester, the students were then invited (not mandatory) to develop an exam set with solutions, preferably in groups. For this, it was not allowed to copy problems directly from the previous exams, although these could be used as motivation. There was no strict requirement regarding the level of difficulty. And it was made clear that the activity was seen as useful for learning in the course, to make the objective clear, and that neither of the sets produced would not be used for the ordinary exam.

Work in groups was encouraged and facilitated. They were then given access to a classroom and regular supervision in a seven-week period. And feedback on the final product was given to all groups participating. A presentation of selected problems was then given by the course lecturer in the final lecture. For motivation there was a draw in the final lecture, where a prize (a book) was given to some random students completing the task.

3 RESULTS AND DISCUSSION

3.1 Results

In total 47 out of the 123 students taking the 2022 course and 39 out of 122 students in 2023, overall, 35.1% participated in the exam initiative, with an additional number participating only in some activities and not completing the task. For example, using the time together with other students to work on exercises with access to supervision and for involvement in plenary discussions.

After the course a questionnaire was sent out to all students, asking for their opinion on whether the initiative contributed to learning. The scores collected from the students responding is summarized in figure 1, referring to a scale from one to five where five is the highest score.

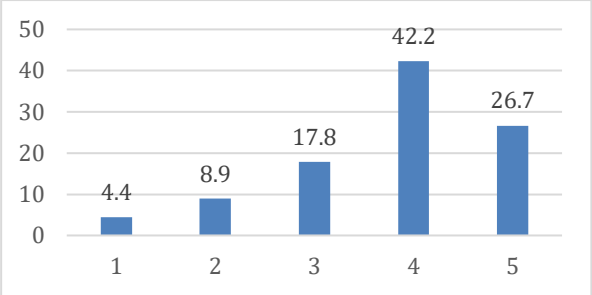

Figure 1 Student opinion on the initiative's effect on learning [%] (n=45)

Except for the initiative, the course design and content have been very much the same over the past four years. In the 2020-2021 period, all lectures were given digitally via Zoom, while in 2022-2023 lectures were given in classroom with streaming. For both periods typically, around 1/3 of the students attended the lectures. In addition, the students had access to recorded lectures and could watch the videos at any time during the semester. For comparison, exam results are summarized in Table 2 and in Figure 2.

Table 1 Exam results 2020 to 2023 [%]

Grade	**2020**	**2021**	**2022**	**2023**
A	10.7	14.7	12.5	11.6
B	17.3	21.3	28.4	18.6
C	30.7	29.3	34.1	32.6
D	20.0	17.3	13.6	16.3
E	12.0	8.0	5.7	12.8
F	9.3	9.3	5.7	8.1

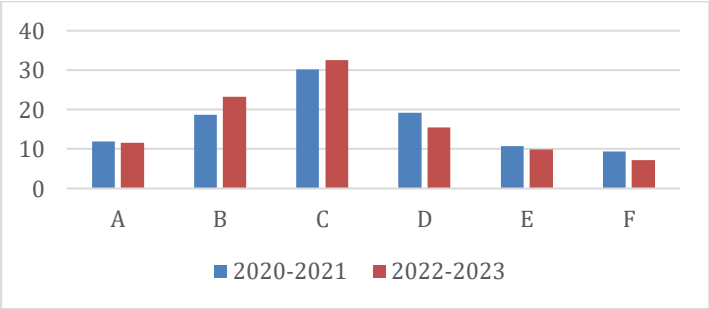

Figure 2 Exam results in the period 2020 to 2023 [%]

From the lecturer's perspective, the initiative resulted in an increase in dialogue with and between the students and an increase in workload. Especially, numbers of e-mail to the lecturer showed a significant increase (almost twice as many), with several students requesting feedback also outside the assigned supervision hours. Many of the requests were on how to solve exercises and previous exams and on alternative ways to approach the problems, and not necessarily linked to the initiative.

3.2 Discussion

The exam initiative can be said to add value by increased reflection on how to solve exercises and previous exams on alternative ways to approach reliability problems. Main feedback being that it makes the students see problems from different perspectives and taking a more active role. Besides, the format to work together with other students on solving a low-stake but value-adding task without direct influence on their grade was appreciated. Students are invited to take an active and more of an explorer role. The idea is to have more focus on student activity and less on what the teacher does, as advocated in Biggs and Tang (2011) and Ambrose et al. (2010). And this should build on the social processes that makes the learning possible (Wittek and Brandmo 2016). the task of developing the exams set with solutions is pointing to basic needs highlighted in contemporary motivational theories, e.g., in the self-determination theory (see Cook & Artino jr 2016) such as relatedness, autonomy and competence. It is a way also promoting ownership, creativity, and reflection. All these being key aspects for facilitation of project work within traditional PBL practice (Otrel-Cass 2016). It is also supported from the course evaluation that the initiative add motivation, and further, that students perceive a positive effect on learning, as shown in Figure 2.

The students perceive a positive effect on learning

Most students have perceived a positive effect on learning from the exam initiative. There could be several reasons for this. Firstly, the initiative can in itself be perceived as positive for their learning. Secondly, the initiative is optional for the students, and it is assumed that autonomy contributes to motivation, which in turn may affect the students' learning (Cook and Artino Jr 2016). Another effect that could also have an impact on the students' opinion on the initiative's effect on learning is that the students see that the university teacher creates a learning arena and spend time organizing a learning activity that is considered as an add-on to the course. The motivation from the teacher by doing this may also contribute to increased motivation for the students taking part in this initiative, which may further lead to a perceived positive effect on learning. In addition to this, the initiative contributes to collaborative student work, potentially fostering enhanced motivation and a positive impact on their perceived learning.

The initiative was made optional, which may also affect the students' perceived effect on learning of the initiative. If it was mandatory, it could have led to a lower level of autonomy, which in turn may lead to students perceive a less positive effect on their learning.

The results are based on feedback from 45 out of the 86 students taking part in the exam initiative. As we do not know if these students are representative of the entire student population, it remains unclear whether we would have obtained similar results if all students were required to participate in the initiative and conducting the survey afterwards. The students that did take part of the initiative may for example have a more positive attitude towards this initiative than the other students. And further, of all the students that took part of the initiative we do not know if those responding to the survey are representative to those not responding. The students conducting the survey can either hold more positive or less positive views compared to those who did respond.

Initiative for helping students succeed individually

The initiative contributes to students being able to prepare an exam paper with solutions on their own, with input from other students and with help and guidance from the course teacher. We consider it fruitful that the initiative is not set up as a compulsory activity, as the students could then focus on topics with which they had little difficulty, if attention is given on getting the task approved more than using the initiative as basis for their learning. The initiative will then have a potential for helping students succeed individually. The challenge by having the initiative optional is that the students who demonstrate the highest willingness to learn, are the most motivated, and dedicate the most time to their studies are the ones who successfully complete the task of carrying out an exam problem set with solutions. The initiative then proposes that subject teachers spend more time on the students who perhaps need it the least, and further, spend the least time on the students who need it the most. However, this is

not considered a problem as far as the time and resources spent does not influence other learning activities meant for all students.

Better results on the exam
The perceived positive effect on learning of the exam initiative also aligns well with the exam results showing better grades in 2022-2023 than in 2020-2021. One may then think that the new initiative has led to better grades. This is one possible explanation, but there are also many other reasons for such results. If we look at the period from 2020 to 2023, it seems that the grades have improved over time. There are more good grades and fewer bad grades in the period from 2020 to 2023. The reason for the improvements in the exam results may then be due to the teacher's experience with the course and subsequent modifications that may have led to course improvements. The changes in the results on the exam can then be fully independent of the exam initiative. There are also many other reasons for changes in the exam results, such as random variation, difficulty of the exam, social aspects, etc.

It is also worth mentioning that even if the exam results are an important indicator for the students' achievement of the learning objectives, one cannot see the achievement of the learning objectives only with reference to the results on the exam. Adjustments can be made from the course teacher if the exam was difficult, so that the results are better than what the score would indicate. In the same way, the teacher can judge more strictly if it turns out to be a particularly easy exam. In this way, the grades only give an indication of the students' achievement of the learning objectives in the course. However, the improvement in the examination results may be an indication of higher achievement of the learning objectives in 2022-2023 compared to the period 2020-2021, as the reliability analysis course has largely remained unchanged during this period. However, one effect of improvements in exam results can also be due to Covid-19. In 2020 the exam in the reliability course was for the first time organised as a home exam. As the time goes by, the students may get better insight into how such exam problems were organised, and this experience may have led to better results.

Time demanding initiative and potential negative side effects on other learning activities
In the reliability analysis course, the exam initiative was added to all previous learning activities as an additional service to the students. However, in most situations such an initiative will influence other learning activities. As teacher and course coordinator you are allocated a specific number of hours which is based on the number of ECTS credits, and the number of students enrolled in the course. An introduction of a new learning activity will then influence previously implemented activities. This means that the real effect of a new learning activity in most situations will be less than first assumed. The effect of the new learning measure may for example in itself have a positive effect on learning, while the overall effect can be negative due to reductions and adjustments in other learning activities. If one disregards such ripple effects, one can quickly end up in a situation where the learning effect turns out to be negative even though the effect of the learning activity itself is positive. This has previously been pointed out in Selvik and Abrahamsen (2022). See also Abrahamsen et al. (2018), Langdalen et al. (2020) and Sørskår et al. (2019).

4 CONCLUDING REMARKS

In this article we introduce an initiative where the exam is used as an instrument for student-active learning in a reliability analysis course. Most students report that the initiative has a positive effect on their perceived learning. Based on the students' feedback, we consider the initiative to be suitable to use in the reliability analysis course, but also for other courses in risk analysis and risk management.

However, it is important to consider the learning effect of the initiative against other initiatives before implementation. Although this study indicates a positive effect on the students' own perception of learning from this initiative, such an initiative could influence other learning activities in the course. It is then important, before introducing a new learning-promoting measure, to assess potential ripple effects. If not, you may end up by implementing a learning measure which can have a positive effect in itself on the students' learning but may lead to an overall negative effect on learning due to changes in other learning promoting measures, ref. the discussions in Selvik and Abrahamsen (2022).

We also argue for making the exam initiative optional, as in this way the conditions are better facilitated for the students to prepare an exam problem set that also cover topics that they find difficult. Introducing the initiative as a mandatory task may result in students prioritizing getting the assignment approved, potentially leading to a focus on topics they are already comfortable with.

REFERENCES

1. Abrahamsen, EB., Moharamzadeh, A., Abrahamsen, HB., Asche F., Heide, B., Milazzo, MF. 2018. Are too many safety measures crowding each other out? Reliability Engineering & System Safety 174: 108-113.
2. Ambrose SA, Lovett M, Bridges MW, DiPietro M, Norman MK. 2010. How Learning Works: Seven Research-Based Principles for Smart Teaching. San Francisco: Jossey-Bass (A Wiley Imprint).
3. Biggs JB, Tang CS. 2011. 1999. Teaching for quality learning at university: what the student does (4th ed.). Maidenhead: McGraw-Hill; Society for Research into Higher Education; Open University Press.
4. Burke K 2010 Balanced Assessment: From Formative to Summative. Bloomington: Solution Tree
5. Cook, DA. Artino jr. AR. 2016. Motivation to learn: an overview of contemporary theories. Medical Education, 50: 997-1014.
6. Gagne M, Deci EL. 2005.Self-determination theory and work motivation. Journal of Organizational Behavior, 26: 331-362.
7. Hmelo-Silver, CE. 2004. Problem-Based Learning: What and How Do Students Learn? Educational Psychology Review 16, 235-266.
8. Jeno LM, Raaheim A, Kristensen SM, Kristensen KD, Hole TN, Haugland MJ, Mæland S. 2017. The relative effect of team-based learning on motivation and learning: A self-determination theory perspective. CBE – Life Science Education, 16(4):ar59, 1-12. https://doi.org/10.1187/cbe.17-03-0055
9. Langdalen, H., Abrahamsen, EB., Abrahamsen, HB. 2020. A new Framework to Identify and Assess Hidden Assumptions in the Background Knowledge of a Risk Assessment. Reliability Engineering and System Safety 200: 106909.
10. Otrel-Cass K. 2016. Good supervision and PBL: Reflections and insights from Master students at the Faculty of Social Sciences at Aalborg University. Department of Learning and Philosophy, Aalborg University.
11. Sambell K, McDowell L, Montgomery C. 2013.; Assessment for Learning in Higher Education 1st Edition. New York, USA: Routledge
12. Selvik, JT., Abrahamsen, EB. 2022. Conceptualization and application of a healthcare systems thinking model for an educational system. Studies in Higher Education 47(1): 1-18.
13. Sørskår, LIK., Abrahamsen, EB., Abrahamsen, HB. 2019. On the use of Economic Evaluation of new Technology in Helicopter Emergency Medical Services. International Journal of Business Continuity and Risk Management 9 (1): 1–23.
14. Wittek L, Brandmo C. 2016. Kapittel 2: Om undervisning og læring. In: Strømsø HI, et. al. (eds.): Når læring er det viktigste. W. Cappelens Forlag AS