Learning approaches studied on newly introduced exam problems

Tiziano Arnone Cardinale, Germán Miranda, Olof Rubin, Axel Stenquist, Philipp Stürmer, *LU, LTH*

Abstract—**The courses students experience first in higher education can set the stage for their future understanding of the subject matter and their choice between a surface or deep approach to learning. Building a good foundation in these areas early on is vital. In this work we study how students learn new problems depending on their learning approach, by focusing on first-semester student performance in linear algebra exams with a newly introduced problem type. We find that by providing prior exams, performance on new problems quickly increases before saturating at a high level. This performance improvement is especially evident for students following a deep approach to learning. While this can suggest that students objectively understand the given sub-topic better, the access to prior exams can also promote a shallow learning approach in a memorization-based examination.**

***Index Terms*—higher education, learning approaches, student performance, time-series analysis, assessment.**

I. Introduction

TRANSITIONING from high school to university can be a stressful and demanding process, and its success is determined by the student's preparation for university and their social, economic, and physical environment [1]. This transition determines the student's academic performance and learning approach [2]. One commonly distinguishes between three types of learning approaches: surface, strategic and deep learning [3]. The stress the first year at university frequently leads to students switching from a deep approach to a surface learning approach throughout their first year [4,5,6,7]. One significant cause of this change in student learning is the influence of assessment, referred to as 'backwash' [8,9,10]. Students often learn and optimize their approach toward what they expect will appear on the exam. Therefore, the assessment method must be aligned constructively with the learning outcomes [11,12].

A deep approach to learning is essential in higher education for becoming an autonomous learner, mastering subject matter, and applying obtained knowledge in new contexts [2]. Generally, more mature students tend towards a deep approach [13,14] as they are aware of context of learning and have experienced appropriate sequencing of learning and problem-based learning [15,16]. A deep approach to learning generally correlates with higher academic performance.

On the other hand, the surface approach is a 'cutting corners' approach [12] and focuses on memorization of facts and procedures. In this approach, a student tries to achieve course requirements with minimal effort, treating the course as unrelated segments, solved using recipe-based solutions [3]. While some subjects benefit strongly from memorizing and thus warrant and benefit from a surface approach, it generally results in lower academic performance [3,12]

Additionally, there is the strategic approach to learning, a mix between the deep and surface approach [12]. In this approach the student still optimizes towards fulfilling course requirements but does so in a competitive nature [17]. Hallmarks of the strategic approach are organized study, time management, and students keeping track of their effectiveness and motivation for learning [18].

A surface approach can give good results in assessments favoring computational problems, but it lacks giving the student theoretical understanding [19,20]. Thus, knowing how an assessment advantages the different learning approaches is essential in exam design [21,22].

In this work, we study exams in the course "Linear Algebra", which is compulsory for most first-year engineering students at Lund University. The students have access to exams from previous years. We focus on a so-called "method of least-squares'" problem, a fundamental technique in linear algebra, which follows a standard recipe. This method was introduced in the curriculum in 2019-20, due to switching the course literature from Ref.[23] to Ref.[24]. A "least-squares"-type problem was introduced on the 2021 exam for the first time. Thereafter, this first exam became accessible to students as a practice exam. Following the backwash effect, we examine whether this accessibility to prior exams for a new type of exam problem affects student exam performance.

Our analysis aims to understand how students with different learning approaches react and adapt to newly introduced exam problems, such as the least square problem.

II. Data analysis & methodology

Our dataset includes information on the performance of 2068 students over seven exams, including the score on the problems, their academic program, their grade, and the date they took the exam. The exam has two parts. To pass the exam (grade 3) requires half the points on the first part. To get a higher grade (4 and 5) requires solving the problems in the second part. The second part of the exam contains challenging problems which are new for every exam and are ideally suited to probe for a deep learning approach. We therefore consider a student as using a deep approach if they achieve a higher than passing grade. The first exam was taken online during the pandemic, and there are no records of which academic program the students belonged to. Table 1 shows the exam performance across all exams and study

Grade Students	Exam 1 143	Exam 2 164	Exam 3 469	Exam 4 241	Exam 5 175	Exam 6 363	Exam 7 513
U	74.83	60.98	65.46	68.46	65.71	46.01	51.07
3	19.58	15.85	24.73	25.31	28.00	45.73	42.10
4	4.20	12.80	7.25	5.39	5.14	4.96	5.26
5	1.40	10.37	2.56	0.83	1.14	3.31	1.56

Table 1: Exam performance expressed in percentage and including grades fail: "U", pass: "3", and above passing grades: "4" and "5".

programs, summarized by grade.

The goal of any exam is to test the student's knowledge of the course goal. Using known problem types that demand a recipe-style solution tests for a basic understanding, thus a surface or strategic learning approach is sufficient. Throughout the seven given exams, ten such problem types occur. We focus on the problems that occur in four or more exams, these are: matrix equations, equation systems, least squares, line intersection, and imaging matrix.

III. Results and Discussion

In Table 1, we see that the first exam has a significantly higher failing rate of 75 % than the following exams. Though this increase in performance does not change the higher grades (4,5).

The higher failing rate in the first exam may be explained due to the pandemic influence [25] or the recent change in the course structure. It should also be noted that this is a retake exam.

The second exam is an outlier as it sees a significantly higher number of students achieving high grades. This improvement is likely due to the higher amount of engineering physics and engineering math students, which have amongst the highest university admission criteria in Sweden. This suggest that these students tend towards a deep learning approach. Interestingly, here the failing rate remains similar.

In Fig.1a we present the average problem and exam performance in percentage for all students. The least square problem (dark blue full line) shows an increase in student performance from 39.2 % to 78.3 %. Also, note that this occurs while average exam performance remains nearly constant at around 59.8 %. The only outlier to this growing trend is the previously mentioned second exam.

Intriguingly, while the student performance on the least-square problem improves over time, the other problems do not show such a trend. We divide the time-series analysis into failing, passing, and high-grade students in Fig.1 b, c, and d, respectively. We observe this trend is most apparent in the failing students in Fig.1b, while average exam and problem performance nearly remain constant for passing and high-grade students.

Passing the exam with a high grade requires a deep learning approach. For these students (Fig.1d) the average exam performance remains nearly constant, even including the pandemic exam. The least square problem, however, has the worst average problem performance in the first exam, it immediately saturates to a high level in the next exam. The same effect occurs for passing students in Fig.1c, which may utilize either a surface or strategic learning approach. Thus, we find our initial hypothesis confirmed that students improve on newly introduced exam problems over time given they have access to prior exams. This increase in time suggests that all students are learning from old exams.

The increase in performance for passing and high-grade students suggest that through using a strategic or deep learning approach students quickly adapt to new problem types if they have access to prior exams. However, these students' performance is initially higher than for the failing students, indicating that their respective learning approach would help them with any new problem type introduced within the first iteration.

IV. Conclusion

In this work a large dataset containing exam performance over a series of was analyzed using a time-series analysis. It was found that exam performance on a new topic improves when old exams are accessible to students. This improvement is especially true for students following a strategic or deep learning approach, which initially perform significantly better than students who do not pass. We also found that this new problem quickly performs better than already long-established problems. This confirms the findings of a previous study [26] carried out in a different setting as well as the backwash effect, where students optimize their learning along prior exams [8,9,10].

Lastly, it is interesting that even the best student groups have similar failing rates, but significantly higher high-grade rates. This near-constant failing rate could suggest that there is a fundamental reason for this in the course structure or that many students lack study skills, which might be amended by a mandatory study skill course, implement in the beginning of the semester or even before [4].

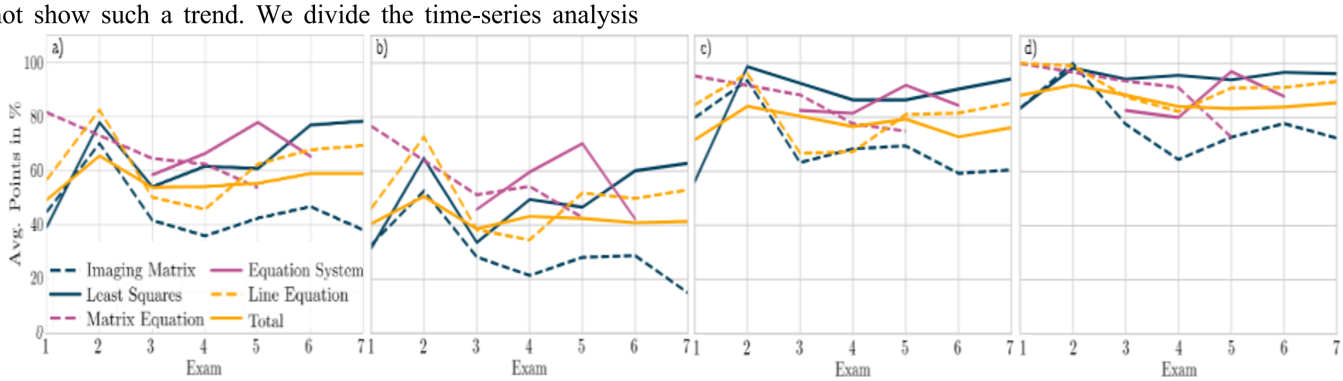

Figure 1: Average points in percentage for exam and problems given in legend for a) all students, b) failing students, c) passing students and d) students with above passing grades (4 and 5)

REFERENCES

[1] V. Tinto, Leaving college: Rethinking the causes and cures of student attrition. University of Chicago press, 2012.

[2] U. Wingate, “A framework for transition: Supporting ‘learning to learn’in higher education,” Higher Education Quarterly, vol. 61, no. 3, pp. 391–405, 2007.

[3] N. J. Entwistle and E. R. Peterson, “Conceptions of learning and knowledge in higher education: Relationships with study behaviour and influences of learning environments,” International journal of educational research, vol. 41, no. 6, pp. 407–428, 2004.

[4] S. Fergy, “The impact of pre-entry study skills training programmes on students’ first year experience in health and social care programmes.,” Nurse education in practice, 2008.

[5] P. Zeegers, “Approaches to learning in science: a longitudinal study.,” The British journal of educational psychology, 2001.

[6] N. F. Jumari, “How do first year malaysian chemical engineering students ap-proach learning,” Chemical engineering transactions, 2017.

[7] M. Lorås, “First year computing study behavior: Effects of educational design,” 2020 IEEE Frontiers in Education Conference (FIE), 2020.

[8] S. M. Abd-El-Fattah, “The effect of test expectations on study strategies and test performance: a metacognitive perspective,” Educational Psychology, 2011.

[9] K. J. G. van Leeuwenkamp, “Students’ perceptions of assessment quality related to their learning approaches and learning outcomes,” Studies in Educational Evaluation, 2019.

[10] L. R. B. Elton, Teaching in higher education: appraisal and training. Kogan Page, 1987.

[11] T. J. Crooks, “The impact of classroom evaluation practices on students,” Review of educational research, vol. 58, no. 4, pp. 438–481, 1988.

[12] J. Biggs and C. Tang, EBOOK: Teaching for Quality Learning at University. McGraw-hill education (UK), 2011.

[13] D. Watkins, “Identifying the study process dimensions of australian university students,” Australian Journal of Education, 1982.

[14] W. Lake, “Age, maturity and gender, and the propensity towards surface and deep learning approaches amongst university students,” Creative Education, 2015.

[15] D. Newble, “The approaches to learning of students in a traditional and in an innovative problem-based medical school,” Medical Education, 1986.

[16] D. Sellheim, “Educational factors influencing physical therapist students’ approaches to learning,” Journal of Physical Therapy Education, 2003.

[17] L. J. Burton, J. A. Taylor, D. G. Dowling, and J. Lawrence, “Learning approaches, personality and concepts of knowledge of first-year students: Matureage versus school leaver,” Studies in Learning Evaluation Innovation and Development, vol. 6, no. 1, pp. 65–81, 2009.

[18] V. McCune and N. Entwistle, “The deep approach to learning: analytic ab-straction and idiosyncratic development,” in Innovations in Higher Education Conference, vol. 30, University of Helsinki Helsinki, 2000.

[19] A. Jacobsen, C. Rump, T. Clemmensen, and M. May, “Kvalitetsudviklingsprojektet “faglig sammenhæng” hovedrapport,” CDM’s skrikserie nr.1, 1999.

[20] M. Elmgren and A.-S. Henriksson, Academic teaching. Studentlitteratur Ab, 2018.

[21] J. Boesen, J. Lithner, and T. Palm, “The relation between types of assessment tasks and the mathematical reasoning students use,” Educational studies in mathematics, vol. 75, no. 1, pp. 89–105, 2010.

[22] W. Cox, “Strategic learning in a-level mathematics?,” Teaching Mathematics and its Applications: An International Journal of the IMA, vol. 13, no. 1, pp. 11–21, 1994.

[23] G. Sparr, Linjär Algebra, Andra upplagan. Studentlitteratur, 1998.

[24] J. Månsson and P. Nordbeck, Linjär Algebra. Studentlitteratur AB, 2019.

[25] A. Werner, “The impact of lockdown stress and loneliness during the covid-19 pandemic on mental health among university students in germany,” Scientific Reports, 2021.

[26] T. J. Wood, “The effect of reused questions on repeat examinees,” Advances in Health Sciences Education, vol. 14, pp. 465–473, 2009.