FACILITATION OF STATISTICAL COURSES FOR THE GROWING AND HETEROGENEOUS STUDENT POPULATION

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Students are motivated differently. Previously at the Norwegian University of Life Sciences, these differences were assessed by a personality screening before and after the flipping of an introductory course in statistics, and researchers found that exam scores improved for extraverted students but not for creative/contextual students. The latter type is generally thought to be motivated by working more freely with realistic projects. To reach out to this group of students, a project-based course was offered as a pilot study. The structure of this pilot course is described along with preliminary results based on a small group of volunteer students. Exam scores were similar for students who followed the flipped course. In in-depth interviews, project-based students reported positive experiences and more motivation toward statistics.

INTRODUCTION

Statistics was historically a theory heavy subject taken by more mathematically oriented students at the university level. This is not the case anymore. Today, "everybody" must relate to numbers and analysis. It is, therefore, crucial to promote foundational understanding of numbers and statistical reasoning/literacy to a broader and more heterogenous group of students. There has been considerable research on students' attitudes towards the subject of statistics. For example, a survey about the introductory statistics course across institutions (Deckard, 2017) demonstrated that students express negative feelings about introductory statistics courses and that they complete these courses with few useful skills. Petocz and Reid (2005) pointed out that students attending introductory classes that focused on statistical techniques found little use for statistics and were more negative about using it in their future professions. In contrast, students who attended classes focusing on more realistic projects with statistical literacy and on interpreting results from analyses were more positive and saw the benefit of using statistics in real situations later in life. Dierker et al. (2012) showed that a project-based approach, which is emphasized as one of the beneficial ways of teaching statistics by Bromage et al. (2022), increased students' engagement, reflection, and ability to apply statistics knowledge.

That students learn differently, and thus are motivated to learn in diverse ways, is well-known. There have been several approaches to cope with these differences. In the 1980's, eight Canadian universities conducted research where they used personality types to describe differences in learning in engineering education students and thus connected psychology with pedagogics. Several studies used personality theory in STEM education (Felder et al., 2002; McCaulley et al., 1983; Sæbø et al., 2015) and showed the importance of considering cognitive differences among students. Sæbø et al. (2015) showed that a traditional lecture style may (dis)favor certain cognitive types. Vinje et al. (2021) described how changing from a traditional lecture based introductory statistics course to a flipped classroom introductory course promoting more active cooperative learning turned out to be more favorable for extraverted students. Although the course was taught in a student-active manner, the course structure was admittedly quite inflexible, with weekly assignments and a compulsory attendance requirement. According to personality theory, this strict form disfavors creative and contextual students. The latter student type is motivated by working more freely with realistic projects where they can learn through exploration and by finding their own solutions (Myers & Myers, 1980).

In fall 2018, the Norwegian University of Life Sciences offered the introductory statistics course in two versions to accommodate a heterogenous student population with individuals who learn best from different learning approaches/settings: (a) flipped classroom with cooperative learning or individual assignments ($n = 197$) or (b) a project-based format ($n = 8$). The goal was to provide students with options, so that they could, by assessing cognitive information, choose the course format that they thought would enable them to obtain the best learning outcome. We wanted to promote more

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metacognitive thinking and increase students' motivation for statistics. The aim of this paper is to describe the structure and implementation of the project-based course format and provide some preliminary results and experiences based on exam scores and in-depth interviews with a small group of voluntary students who followed the new course format.

METHOD AND MATERIAL

Participants

Recruitment was done among all students who took the introductory statistics course in the autumn semester of 2018. To assess the cognitive diversity of the student population, all students were first offered a short version of a STEM-education profiler, the Education Test (Brovold, 2020). It is a self-assessment questionnaire containing four sections: (a) a short personality trait profiler section based on the dichotomy types of Jung (1921) and Lowen (1982) (see, e.g., Vinje et al., 2021 for a closer description of the traits); (b) a section assessing work interests; (c) a section assessing preferred learning instruction methods; and (d) a section assessing interest level in six areas of STEM education. The test output gives an indication of how a student learns best. Students also received an introductory lecture addressing meta-cognitive aspects of learning to make them reflect upon their own learning approaches. We encouraged students who, according to the Education Test, liked to approach subjects "from top to bottom" as well as students who initially knew that they liked project-based learning to apply to the project-based course. The project-based course was then completed with eight students who were motivated and had reflected on why they wanted this course format. Of those eight, three had signed up for the introductory statistics course during an earlier semester but withdrew from the course during the semester or had taken the exam but not achieved a desired grade. These eight students were randomly divided into two groups that they kept throughout the course.

Course Contents and Projects

Students following the project-based format had access to the same learning resources on the course learning platform (Canvas LMS by Instructure) as students following the flipped classroom format. The learning resources were comprised of the textbook (Løvås, 2008), lecture videos (5–20 minutes long) addressing the course subjects and learning goals, videos of example exercises, lecture notes, weekly quizzes, and historical exam exercises. For the project-based format, these resources were offered freely for use, but students did not need to complete the weekly assignments (which were required for students in the flipped format). However, students in the project-based class had to complete the online quizzes before the exam.

Three projects were required in the project-based course. Each project lasted for three weeks. In each project period, the course instructor was available for two hours, twice a week, throughout the project periods. Students were only required to attend the first and last lesson of each project period. Students also had access to a room on campus designed for project-based work. The students chose to spend all available hours with the course instructor and in discussion with their own group. After the end of each project period, there was an hour of formative evaluation. Here the two groups of students presented their projects and results to each other, and we had a discussion based on the results and conclusions. This evaluation did not count as part of the final evaluation or grading of the students, but it laid the foundation for the discussion on the oral exam at the end of the course.

The first project dealt with sampling theory, estimation of parameters, and uncertainty associated with estimation. Data for the project were simulated and represented an election poll from a fictitious country. The assignment was to make a film (news broadcast) where students would present the results and implications of the poll. The second project dealt with hypothesis testing to compare two or more groups; students used both *t*-tests and Analysis of Variance (ANOVA) for analysis. Data were obtained from an ongoing project at the university. Students were to present results with conclusions in the form of a written report and a presentation to the rest of the students. In project three, the students used their own data collected from an introductory course in microbiology. They conducted linear regression analyses for the project. Each student was supposed to add a statistical part to the lab assignment in the microbiology course and to make an instructional film that explains the theory behind regression analysis for students.

Although the idea was that students should learn the introductory statistics content by discovering it for themselves through problem solving, we were concerned about maintaining statistical

and scientific rigor. At the end of each project period, there were exercise classes where the project-based students solved the same exercises as students from the flipped class and answered mandatory multiple-choice tasks that focused on underlying theory and calculations.

Exam

According to the framework of constructive alignment, assessment of learning should align with learning activities and learning outcomes. Because learning activities for the project-based course were quite different from activities in the flipped classroom format, these differences had to be reflected in the exam format. With a large emphasis on oral presentation during the project-based course, a central part of the assessment was therefore in the form of an individual oral presentation. Hence, 50% of the grade was based on oral presentation and questioning for one of the three projects completed in the course. However, students also received a questionnaire containing 20 multiple-choice questions. The multiple-choice exercises were given to all students following both course formats, and they were designed to test both arithmetic and computational knowledge as well as basic conceptual understanding in the subject of statistics. These exercises were similar in form to the weekly quizzes provided throughout each course for all students. In addition to assessing these other learning outcomes, the multiple-choice exercises served as a control for evaluation and comparison of the achieved learning outcomes for the two course formats. In addition to the multiple-choice exercises, the exam for the flipped classroom course consisted of a set of written exercises, including a longer written text assignment (counting 50%). The written exercises for this group of students covered the same main topics in introductory statistics as the three projects of the project-based course but were otherwise not similar. However, all exercises/projects for both groups were carefully designed to assure they reflected the same learning outcomes.

Qualitative Interviews

Approximately 1–2 months after completing the course, all candidates from the project-based course were interviewed about their experience in the project-based version of the course and how this form of teaching and learning affected their motivation in the course. The interview was conducted by a person well trained in qualitative pedagogical evaluations and who was not affiliated with the course. This was done to reduce the probability that students' loyalty to the course instructor would affect their answers. The interviews were transcribed word by word, and an initial coding using motivation codes built on the framework of Ryan and Deci (2000) was done by the course instructor and the interviewer separately. Codes were then compared to arrive at a consensus.

RESULTS

An overview of the eight course participants and their personality traits is provided in Table 1.

Table 1. Overview of personality traits of project-based course participants

Total	Extraversion/Introversion	Intuitive/Sensing	Feeling/Thinking	Digital/Contextual
8	6/2	5/3	6/2	1/7

Seven of the eight project-based students completed the exam. The dropout was due to disease. For the oral presentation, the average grade was between a B and a C. For the multiple-choice questions, the average score was 15 correct out of 20. The flipped classroom students had an average score of 15.1 on the same multiple-choice questions.

The mathematical background of project-based participants varied, both in terms of results and course levels completed. Most participants came from natural science study programmes at the university, which do not require more mathematics than an introductory calculus course. With reference to the taxonomy of human motivation in Ryan and Deci (2020), several of the eight participants reported amotivation, or low extrinsic motivation, towards subjects such as mathematics and statistics in interviews after the course. Sample phrases used were “do not have a math head” and “have never done well in subjects with a lot of numbers.” In the interviews, it was further reported that they had learned a lot and gained more motivation for the subject of statistics. Several students pointed out that they had clearly seen the usefulness of the subject and the close relationship between domain knowledge and

statistical methods, and they coded higher on motivation, more in the direction of *Identification* and *Integration* under extrinsic motivation (Ryan and Deci, 2020). The following two quotes from students reflect this.

- A good thing was that we were able to work more freely and look for the solution ourselves and compare this to the project. I feel that it contributed to a deeper understanding of statistics. And one of my goals in taking this course was to gain a deeper understanding of how I work with tasks like this.
- It has helped me a lot to actually understand statistics in a completely different way and gained much better knowledge.

Project three was highlighted more often than the other two as exciting, educational, and motivating. It was this project where domain knowledge was closest to the subjects several of the participants themselves studied. Even though several participants reported that the realistic project and the project-based approach to working on them was appealing, we did still find answers coding in the lower scale of extrinsic type of motivation towards the field itself after the course ended. In the interviews it was also reported that the project-based course was time-consuming, both because there were larger projects over longer periods, and because there were many new aspects of learning that took considerable extra time. For instance, they spent a lot of time filming/editing and preparing for presentations.

The pilot project resulted in a teaching collaboration between the statistics and microbiology environment at the Norwegian University of Life Sciences (NMBU) to create interdisciplinary learning resources for use in both disciplines.

DISCUSSION

Project-based teaching was introduced primarily as part of a larger pedagogical project on how to adapt statistics training to the larger and more heterogenous student population that enrolls in our university today (Sæbø et al., 2015; Vinje et al., 2021). At the same time, such a way of working is useful and relevant to how students might encounter statistics throughout their degree programs and in their future professions.

Our experiences and observations indicate that a project-based course can increase the motivation of students who are not themselves motivated for theoretical disciplines such as statistics, e.g., contextual and intuitive students such as the majority that participated in this pilot project. The majority of those who completed the project-based course reported that it was a motivating approach for them to work on larger projects with a clear connection to reality, which is expected based on previous literature (Bromage et al., 2022; Dierker et al., 2012). The result is strengthened by the fact that project three was highlighted as the most exciting among the students. Project three was closest to the students' studies, and several of the students had themselves been involved in generating data through a laboratory exercise in the introductory microbiology course. At the same time, this project was the last in the course, and the students had therefore learned more statistics before they started applying regression analysis. This was perceived to be particularly motivating by the students. Linear regression is close to the mathematical concepts they have studied since the upper secondary school level. Even though they reported higher motivation after the course, several of them did not link this motivation to the statistical subject but rather to the teaching method.

Even though our results indicate higher motivation, we should emphasize that these results are limited to the fact that there were only eight participants in the project-based pilot study in 2018. There are also major challenges associated with scaling up such a teaching method. Personal follow-up with eight students is feasible, but with 400 students, it will have to be solved in a different way. With such upscaling, one may lose the close teacher relationship and part of the motivation this brings. We must therefore be careful about generalizing the results from the study even though our findings aligned well with our prior hypotheses.

The fact that the students perform adequately on the oral exam part is not surprising. They have discussed the problems together in groups and with the course instructor throughout the course. The project-based students performed just as well as their peer statistical students attending the flipped classroom version of the course on the multiple-choice assignments. When we created the course, we were concerned about whether we would manage to maintain the same academic level and quality of teaching statistics in the project-based version, i.e., whether the students would acquire not only practical application the methods, but also the theory behind the methods. Because it was known that

several of those who took the project-based course had attempted to learn statistics earlier and/or reported a lack of motivation for "subjects like this," it was thus reassuring that they achieved the same average score as the students in the flipped classroom course. Whether it is because they participated in teaching that motivated them to work more with the subject, or if project-based courses made the content of the subject more accessible to them so that they understand more of the course content, remains unanswered. The conclusion we can draw is that for several of these eight students, a project-based introductory course in statistics was beneficial.

As mentioned above, project-based students reported the interdisciplinary project as the most interesting. They recognized which analysis they needed to do and were able to draw conclusions from their analysis. From both the research literature and our own teaching experience, we know that students absorb the material better, are more motivated, and see the usefulness of the subject of statistics in a completely new way when they work with examples and data that are relevant to their education (Ben-Zvi et al., 2018). Educational institutions at all levels, from primary school to university, now promote interdisciplinarity. But teaching classes that are both project-based and interdisciplinary presents several challenges. For instance, educational institutions are often organized both academically, physically, and economically according to scientific disciplines in autonomous units. Unfortunately, this promotes silo-thinking and is counterproductive for the possibilities of facilitating interdisciplinarity studies. Furthermore, it is quite common that study programmes are filled with mandatory courses that leave little flexibility for students to partake in other courses to expand their horizons.

CONCLUSION

Even though interdisciplinarity is a declared goal at several levels in the educational system in Norway, it can be challenging to achieve. Based on the feedback we received from the project-based course, our pilot with eight students has been the start of interdisciplinary learning resources in statistics and microbiology at NMBU. We believe these results make an interesting contribution to the discussion around teaching approaches in statistics and that it can benefit a wider student population. Not all courses should adopt a project-based and interdisciplinary teaching and learning approach. Whether this is a way of learning that should be provided only to contextual and creative students should also be discussed on a larger scale, but introducing real and perhaps “familiar” data and in that way weave interdisciplinarity study into statistics is beneficial. As Felder and Brent (2016) emphasize in their book, the goal for educators should be to teach in an inclusive way that helps as many students as possible to succeed. Where, when, and how domain knowledge and analytical methods should be integrated in the educational process remains open for further discussion.

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