EXPERIENCES WITH MULTIDISCIPLINARY PROJECT AT THE PREPARATORY COURSE FOR ENGINEERING STUDIES

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Abstract

This article reports on experiences gained during a one-week multidisciplinary project at the Norwegian University of Science and Technology, Trondheim, Norway (NTNU). The projects primary aim was to explore a possible method of facilitating a multidisciplinary learning environment across the subjects Technology and Society (TS), Communication and Norwegian (CN), (introductory) Physics and Mathematics. Secondly, the project aimed to observe the potential of meta learning as a bridge to multidisciplinary approaches.

The projects' primary motivation was to try out a possible angle for multidisciplinary work, across all its subjects, such that similar projects could be implemented at the entire course the following year. Further, putting an emphasis on meta learning was deemed an interesting approach of attempting to develop critical thinking among the participants, and to further highlight the connection between subjects.

A group of approximately 50 students from the Preparatory Course for Engineering Studies at NTNU were divided into groups and given in total 11 tasks/themes to choose from. All the tasks in some way involved the subjects TS and CN, while either physics or mathematics formed the main body of each task. Further, some of the tasks involved some level of meta learning by referring to pedagogical and didactical aspects of STEM-courses. The groups were instructed to produce a research question and hypothesis relating to their task, collect, and analyze data, and write a report on their findings. Each group was to present their research and results to the rest of the class after the project week.

In general, the project yielded a high degree of participation from the students. Using surveys, experiments, and literary analysis, they achieved many interesting results. Particularly, some students analyzed their peers' perceived effectiveness of some of the main teaching and learning methods implemented thus far in each course. After the project's conclusion, we noticed both more conversations within the student groups and more collaboration across them. Some students also expressed that they felt more motivated after the project. However, the project yielded little to no noticeable difference in test results, neither in physics nor mathematics.

Keywords: Multidisciplinary learning, collaborative learning, meta learning, engineering studies

1 BACKGROUND

This article reports on experiences gained during a one-week multidisciplinary project at the Norwegian University of Science and Technology, Trondheim, Norway (NTNU). The projects primary aim was to explore a possible method of facilitating a multidisciplinary learning environment across the subjects Technology and Society (TS), Communication and Norwegian (CN), (introductory) Physics and Mathematics. Secondly, the project aimed to observe the potential of meta learning as a bridge to multidisciplinary approaches.

The projects' primary motivation was to try out a possible angle for multidisciplinary work, across all its subjects, such that similar projects could be implemented at the entire course the following year. This came as a result of the revision of the national curriculum for the Preparatory Course for Engineering Studies in Norway, to be taken into effect as of August 2022. Here multidisciplinary work is listed as an important (and obligatory) part of every subject connected to the course. Thus, finding a way to properly introduce multidisciplinary factors into our teaching became essential not only to meet the national guidelines, but also to introduce the many potential benefits of multidisciplinary work. One such benefit could be the connection of elements that would otherwise have remained unconnected [1]. Further, multidisciplinary teaching may naturally lead to student-centered education [2]. It is also emphasized by NTNU, through a report on the Future of Technology Studies, that multidisciplinary approaches should become a prominent part of the university's teaching practices in the coming years [3]. Thus, this project could be seen as a measure to meet some of the primary objectives of the institution.

2 INTRODUCTION

A teaching week at the Preparatory Course for Engineering Studies normally consists of 32 hours. During the project week, these hours were allocated to the project. However, the teachers required that the students worked beyond these hours, as we expect a workload that exceeds the assigned sessions.

The students were separated in groups of five or six, and these groups were organised by the teachers. The combinations were not based on academic achievements, but rather on creating well-functioning and heterogenous groups where each member could contribute actively. Thus, the groups were based on social aspects rather than academic qualities.

The project has several intentions and goals; explicit learning aims, as well as implicit effects that can contribute positively to students' learning. In the course Technology and Society (TS), crossdisciplinarity, cooperation, critical thinking and scientific methods are essential parts of the learning outcomes. These skills are also valuable components of many humanities courses, but they are problematic to teach in a classroom. Nevertheless, by conducting experiments, problematising and testing hypotheses, it is likely that students attained a greater understanding of some of the course's learning aims.

In the course Communication and Norwegian (CN), the project also wished to meet certain learning aims. After a year at the Preparatory Course for Engineering Studies, the students should be able to communicate well and efficiently in groups, plan and conduct meetings, and write a variety of project documents. During the project, the groups had to hold meetings where meeting notices and meeting minutes had to be written. In addition, the project had to be explained thoroughly in a project report. Thus, the planning and conducting of these meetings, as well as the writing gave students relevant practical and theoretical experience.

The relations between the project and Mathematics can largely be identified by two learning aims; student should be able to express themselves mathematically, as well as display proper use of mathematical relationships, and they should be able to communicate with others about scientific problems.

In Physics, the project aligned with many of the general learning aims of the course. After completing the course the students should be able to explain scientific principles, and communicate with others concerning scientific problems using concepts and terms from Physics. Further, more directly, the students should be able to perform scientific experiments at a safe and qualified level, take measurements, interpret results, and write a report. Thus, the project could meet many of the more practical aspects of the Physics course.

During the period, the course teachers worked as facilitators, and there was at least one present on-campus through the assigned working hours. In addition, the teachers could be reached by email and on Blackboard.

3 METHODOLOGY

In order to take the exams at the Preparatory Course for Engineering Studies, several compulsory assignments must be approved. Some of these obligatory assignments were part of the project, and by participating during the project week, students completed at least one assignment in each course. The project was placed at a suitable time where the teachers found it beneficial with a break from normal day-to-day teaching which mainly consists of lectures and completion of tasks. Since many of the learning aims from TS and CN were tested by the project itself, the topics to be researched were from to the other two courses.

The project was included in each of the primary subjects' (TS, CN, Physics, and Mathematics) compulsory work in various degrees. For Mathematics and Physics the project counted towards the respective subject's total amount of obligatory activities (9 out of 13 and 6 out of 9, respectively). It was therefore possible to be eligible for the exam in these two subjects without participating in the project. However, for both TS and CN the project was deemed compulsory, meaning that the students had to participate in the project and get an approved report in order to be permitted to take the exam. Further, the oral presentation of the students' findings also counted towards the total amount of obligatory activities in CN. In none of the subjects did the project count towards a final grade.

3.1 Group work

Problem-based learning, group work, projects and field work are some of the teaching methods explicitly mentioned in the quality reform for higher education in Norway, which was implemented as of autumn 2003 [4]. In other words, there is a wish to facilitate for student active learning and participation instead of traditional lectures. This project is therefore aligned with these political guidelines.

According to Johnson et al, learning in a cooperative environment is dependent on five fundamental aspects: positive codependency, individual responsibility, stimulating interactions, social skills, and process evaluation [5]. By the way the project was designed, and the groups constructed, it is suggested that these five aspects in theory could have a higher likelihood of becoming present. Thus, the group work facilitated in this project was deemed to have a higher chance of being successful.

3.2 Mathematics

In the present work, mathematics learning was a central part of four group projects; namely, the golden ratio (3 groups), and the derivative and limits (one group). The former project was introduced to the students by the following task:

> Find examples of the golden ration within architecture and arts. Why does the human eye prefer the golden ratio? Investigate whether the golden ratio is more appealing to people than other geometric ratios.

For the latter project, the following task was given:

> What are the barriers to students' process of understanding limits and the derivative, according to research? Investigate possible attitudes displayed by students at the Preparatory Course towards these mathematical topics. Try to assess the knowledge students have of e.g. the definition of the derivative, graphs or other visual interpretations and examples, Leibniz notation and derivative rules. If possible, obtain an overview of misconceptions which the students have had in the learning process.

3.3 Physics

In total six of the groups were equally divided between three different physics-oriented tasks. Two groups were to choose their own theme for exploration, two were to explore possible outcomes of ice melting, and two were asked to evaluate the "effectiveness" of different methods of heating food products. Specifically, the tasks read:

> **Open task:** Find a theme in Physics you would like to explore. Design and execute an experiment which tests your hypothesis. Write a report on your findings.
>
> **Ice melting:** In Physics you have learned about buoyancy. Design and execute an experiment which shows what happens if land ice or sea ice melts. Compare your results with theoretic calculations.
>
> **Heating:** You can find a lot of contradictory information concerning how to heat frozen goods most effectively. Design and execute an experiment showing various methods of defrosting food and rate the methods according to their effectiveness. Justify your results based on your textbook, as well as other sources.

The tasks were designed in such a way that they would be open for interpretation. Some words were intentionally left undefined, such as "effectiveness", so that the students would have to find their own definition based on their research question.

As one of the main goals of the project was for the students to find their own approach for solving their task, the level of aid was constantly evaluated accordingly. The only times the groups were guided into a greatly different direction were when the research question would require too much time or too many resources. In addition to aid from teachers, the students working on the heating and ice melting tasks were given some sources as a starting point. These sources were picked in such a way that they would provide as little help as possible in the actual production of a research question, while still being useful when reflecting on results.

3.4 Meta perspective

A highly important element in the present work was to look for factors relating comprehension of a mathematical or physical topic to students' didactic research. We wanted to create a good framework for students to investigate their own learning of the topics in question.
As a means of testing how tasks with a meta perspective could be implemented as a bridge to multidisciplinary approaches, two tasks concerning STEM subjects were produced. Firstly, one group was asked to look at the learning and teaching methods implemented at the Preparatory Course:

> How can one best adapt one's own learning process for learning Mathematics and Physics? What does the research say? Investigate which learning methods the students at the Preparatory Course prefers.

Lastly, one group was to explore practical and theoretical approaches to Physics:

> Physics is at its base a practical subject, where experiments and demonstrations play a central part. Discuss the difference between a theoretic and a practical approach to the subject and point out some advantages and disadvantages of both the approaches. Build a hypothesis concerning learning through practical or theoretical means, and test is against the class's experiences of experiments and demonstration from the teaching.

The task concerning practical and theoretical approaches also contained some useful sources.

4 RESULTS AND DISCUSSION

While many interesting tendencies could be speculated about and observed, the project resulted in experiences that were difficult to measure and highly subjective by nature. The results of the project were as follows.

4.1 Results in Mathematics

While it was assumed that learning goals in mathematics would be met by doing calculations, some of the groups chose projects based on mathematical topics. Particularly of interest for the present work, the project group "Derivatives and limits" investigated barriers towards efficient learning comprehension of these topics. As part of the project, the group carried out an online survey among peer students. The participants in the survey were to solve tasks concerning the derivative and limits, of relatively standard difficulty for the curriculum.

The theory of limits is normally a challenging topic for preparatory course students, which coincides well with cases in published literature where undergraduate students have been assessed [6]. The difficulties with grasping the concept of limits may be due to unfamiliarity with the mathematical notation or the abstraction involved in the way we think about limits, in which a variable must approach a value but not be equal to it. Discussions with the students through the work indicated that their project enhanced their consciousness regarding efficient learning.

4.2 Results in Physics

In general, quantitative results, i.e., results from tests and exams, displayed little to no change after the project. However, some of the less directly measurable results could be interesting to investigate further. Even though the students were familiar with each other before the project, students from the groups who worked on the physics tasks (subjectively) displayed some higher oral participation in class following the project. They both posed more questions and raised their hands more during lectures and exercise sessions.

Further, some of the groups displayed a strong will to explore themes beyond the scope of the course, thus needing books and articles form higher-level physics in order to sufficiently discuss their topic. These groups were more difficult to guide, as it was hard to draw the line between the themes they wanted to explore, and the time needed to properly benefit form the project. Furthermore, it was difficult to highlight the multidisciplinary aspects, as the mathematics needed to suitably portray the concepts in question was (at the time) of a level beyond the reach of the students. This then resulted in more Physics oriented projects than originally desired.

Even though multiple groups worked on the same task, it was interesting to observe the vastly different approaches they chose to implement. While some groups chose to use already established theory to build their hypothesis, others opted to use personal experience as their main path of exploration. Moreover, this led to interesting discussions between groups with similar tasks. Particularly, discussions of climate change and how physics could be used to debunk conspiracy theories arose without prompting from a lecturer.

4.3 Results in the humanities courses

The students had to have a practical approach to something they had only learned theoretically, and although it is complicated to measure the results obtained for the humanities courses, some learning outcomes are still visible. In conjunction with the report, the groups also had to submit formal documents such as progress plans, meeting documents and cooperation agreements. These practical documents were aimed to help the groups structure the process, and the feedback on these documents and meetings was positive. More specifically, students claimed that they helped structure and plan the week as well as made the process more predictable. Furthermore, the project report needed a specific structure, and although their work cannot be considered as scientific, the students still learned more about what scientific writing is. Thus, by writing such a report, students are hopefully more prepared for their future studies and work.

4.4 Results of the meta perspective

The meta perspective resulted in some quite fascinating and varied results. The task concerning the teaching methods at the Preparatory Course produced a report comparing specific learning and teaching methods implemented at the course in relation to students' perceived effectiveness of each method and separated by the students' preliminary grades. While specific topics from Mathematics and Physics could not directly be correlated to this report, many of the implicit goals for the subjects could be argued to be met through debating this topic. This naturally led to discussions about theoretical and practical physics, the use of group work in mathematics and similar. Thus, this specific form of meta learning does not look to reach the explicit goals of these two subjects, but rather some underlying and desired qualities in both. In addition, these types of meta tasks do indeed meet the goals of the subject TS and CN.

Further, the groups working on the meta tasks did (as expected) need different guidance than groups working on the other tasks. As the concept of learning is rather vague, the students working on these tasks needed to express themselves in ways they may not have been used to. It could also be seen a great contrast between the practical Physics groups and the meta groups, as the Physics groups asked more about the execution of experiments and help with calculations, while the meta groups were more concerned with wording and available research.

CONCLUSIONS

This project has led to many fascinating findings. Firstly, our results suggest a high potential for sparking discourse and exploration of new topics. We observed a higher degree of oral participation after the project had concluded. Secondly, the students reacted positively to the project, claiming that it made them more motivated for continued studies. Further, using a meta perspective as a bridge to multidisciplinary approaches looks to be a promising method of promoting the more implicit and subtle aspects of Mathematics and Physics, while directly meeting the goals of TS and CN.

Following the project, it is clear that many aspects need to be investigated further. Our first course of action is to implement a similar project across the entire Preparatory Course, which consists of three classes. We will use the experiences gained throughout this project to improve and professionalize the strategies employed as to further strengthen the subject-to-subject learning outcomes, in addition to highlighting the key multidisciplinary aspects of such a project.

In the future, we see much room for further research where, for example, two of the three classes could participate in the multidisciplinary project, while one acts as a control, in an attempt to measure the learning outcomes of such projects. It could also be interesting to further investigate the potential of meta learning in a more controlled environment.

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