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Implementing a practical learning approach into civil engineering education for BYGA2022 – Construction safety and statics. Student outcomes and judgment

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Abstract

This paper presents results from the modification of BYGA2022 course – construction safety and statics, taught at the Norwegian University of Science and Technology for 4th-semester students on a bachelor level. The course aims to provide knowledge on how to calculate and apply external forces acting on different types of structures and how to ensure the required level of safety in structural design. In order to meet those goals, the course was thoroughly modernized and ran in the new form in the spring semester of 2022 for the first time. Modifications included preparing new lectures and exercises with real-life examples, introducing engineering software used in practice, and implementing an individual project into the course curriculum. Implemented changes met with a positive response from students, increased engagement, and a better understanding of the entire design process. Results of implemented changes were accessed using feedback from a reference group an anonymous survey, and examination results.

Keywords: practical learning, project-based learning, civil engineering, higher education

1 Introduction

1.1 Background

A proper course design is essential for achieving desired educational outcomes among the course participants. Often privately held courses must be revised constantly to stay profitable, relevant and meet the needs of future participants. However, in the areas where there is a lack of such incentive, some courses can easily become outdated and do not fulfill certain standards/requirements making it difficult to provide skills desired on the job market. This is especially true in more conservative disciplines such as civil engineering, where theory is often emphasized, and instructors focus on fundamental knowledge with little reference to practice, especially if they have no industry experience. Such education can result in poor performance of civil engineering majors (Shi, 2014), increasing the gap between course syllabus and skills required by companies (Arlett et al., 2010; López-Querol et al., 2015; Nehdi, 2001; Ruiz-Teran & Aparicio, 2007), making it difficult for students to relate theory to practice (Shaaban, 2013). Therefore, although providing a strong theoretical background is essential in engineering education, the author believes that students would benefit from a more practical approach with real-life examples, the use of relevant engineering software, and individual project. Those teaching methods are believed to have huge potential when it comes to developing engineering judgment, independent thinking, and a broader understanding of the challenges engineers have to face (Audu et al., 2014; Moore et al., 2014; Shaaban, 2013).

A recent study from the University Of Gondar and Addis Ababa University shows that over 80% of students disagree with a statement that teachers relate theory to practice while teaching in class and underlines this fact as one of the main issues in civil engineering education (Shiferaw, 2022). This number may be somehow shocking, but on the other hand university educators often lack industrial experience making it difficult to provide relevant examples. Other studies identified that many engineering student graduates suffer from a lack of problem-recognition and solution skills (Evans et al., 1993; Scott & Yates, 2002). Looking more locally, a survey among civil engineering students in Norway indicates that students would like to see the practical use of a theory they are learning (Grabmukkerova, 2017). The survey suggests that in this way students would gain more engagement and lectures would be therefore more interesting. This is also confirmed in the literature, where an increase in student motivation was observed when more practical teaching approaches have been implemented in the course (Ruiz-Teran & Aparicio, 2007).

This paper aims to identify flaws/places for improvements in one of the elementary civil engineering courses at the Norwegian University of Technology (NTNU), describe implemented changes needed to offer a new, revised, more practical course content, and discuss outcomes from students' perspective. The goal of described herein work was to enhance students' competencies in structural engineering through the implementation of a practical learning approach, implementation of more engaging learning methods, and education of engineering software, such that course participants understand better challenges in their future civil/structural engineering jobs.

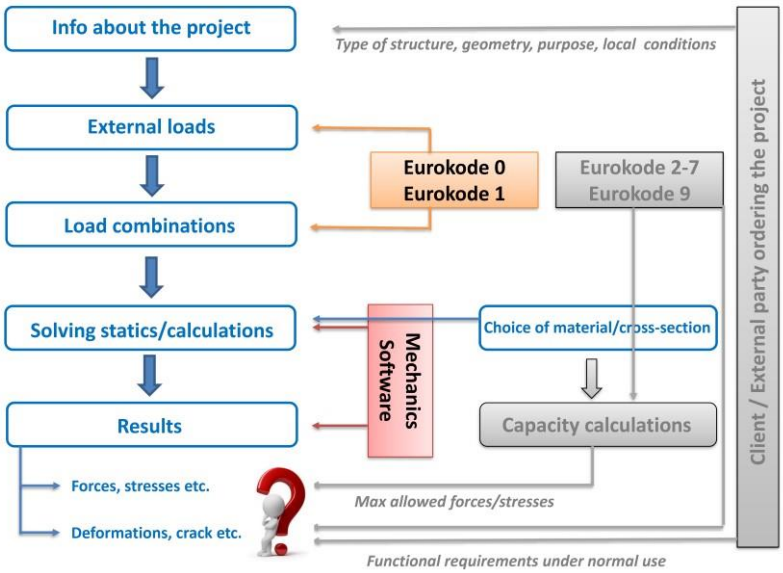
1.2 Problem statement and objective

BYGA2022 – Construction safety and statics course is a 4th semester thought at the Norwegian University of Science and Technology (NTNU) in Ålesund for civil engineering study program on a bachelor level. The course is an elective, and it is usually selected by students who choose structural engineering as their specialization. The course aims to provide knowledge on how to perform necessary calculations that will ensure the safety of designed structures and allows students to familiarize themselves with the design process shown in Figure 1.

The author of the paper overtook part of the course in 2021. After getting acquainted with the existing curriculum and teaching methods, the following issues with the BYGA2022 course were identified:

- Due to the heavy focus on the theoretical part of the course, students are not well prepared to face problems in their future jobs as civil engineers/designers. Exercises are limited to solving very limited tasks, making it difficult for students to understand the whole design process from "A to Z" and get the feeling of how the job of a structural engineer looks like.
- The curriculum does not include a sufficient number of practical examples. The course materials lack examples taken directly from industry, and real case studies/scenarios.
- Course content does not acknowledge that a lot of tasks of designers are nowadays automized and performed by using engineering software. Without proper education and introduction to engineering software, students struggle with interpreting results and make a lot of wrong assumptions and mistakes using the software which is seen later when supervising students writing their bachelor thesis.

Figure 1: Flowchart of the design process. Colored modules were included in the BYGA2022 course



Described in this paper projects aims to address all the above, currently existing shortcomings through the implementation of a practical learning approach, analysis of practical examples, and education of engineering software. Chapter 2 describes implemented changes to BYGA2022 to solve described issues. Discussion about achieved results can be found in chapters 3 and 4.

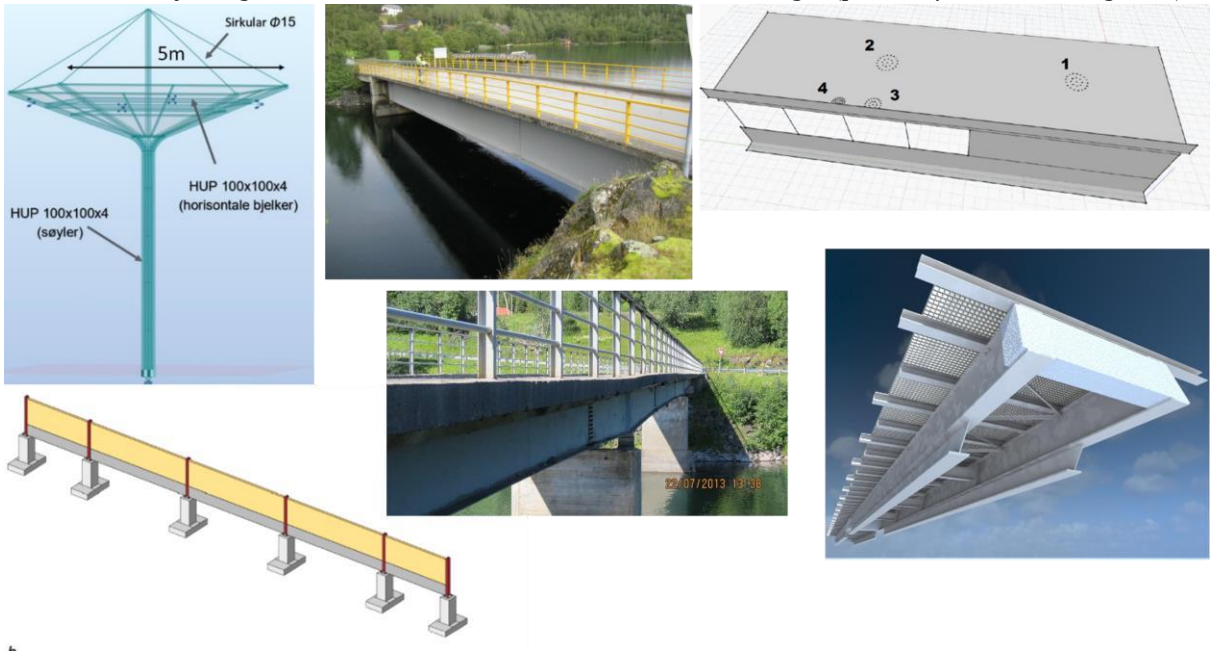
2 Methodology

2.1 Lectures and exercises with practical examples

As pointed out by Shaaban (2013) engineering graduates can benefit more from university education when civil engineering courses are taught by instructors that have both academic and practical experience (Shaaban, 2013). Practical experience makes it possible for instructors to help in relating theory to practice, improve problem-solving skills and develop engineering judgment that allows students to evaluate obtained values, quantities, and dimensions. In addition, considering realistic design projects has the potential to increase engagement and motivation to study among students. Therefore, it should be easy to understand why studies show that civil engineering education could be enhanced through the use of case studies (Chinowsky & Robinson, 1997).

Considering real-life examples is the first tool that was used in the revision of the BYGA2022 course to make the subject more practical. In addition to the benefits of case studies mentioned in this chapter, the author was hoping that through analysis of practical examples taken directly from the industry and real projects, students will have a chance to understand the roles/challenges/responsibilities of structural engineers as well as how design process looks like. In other to achieve these goals a 3-year experience of an educator as a structural engineer was utilized. The author worked mostly as a bridge designer but has also experience in designing a variety of other objects from buildings to marine structures. In addition, he worked also on the construction site and IT company that provides software for engineers. Those experiences were utilized to provide a better overview of how different disciplines blend/work together to provide a final product: a building, a bridge, or another infrastructure object. Some examples of structures being considered as examples/case studies are shown in Figure 2.

Figure 2: Some examples of structures used as case studies in the BYGA2022 course: snow collector, noise screen, railway bridge, snow/avalanche shed, Nevernes/Hamnsund bridges (pictures from Statens Vegvesen)



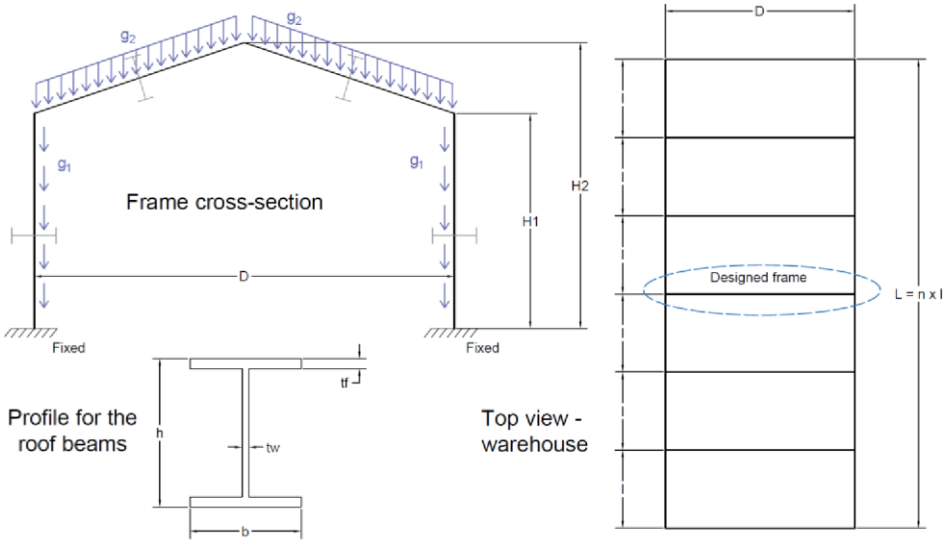
Another novelty was conducting some of the lectures in English. There were two main reasons for doing that. Firstly, many of the largest construction projects in Norway require documentation in English, and therefore introducing some technical vocabulary in that language was considered to be beneficial. Secondly, the number of additional materials and literature in English explaining principles of design, how to use standards (Norway adopted European Eurocodes) as well as software manuals/tutorials are disproportionately larger compared to what is available in the Norwegian language.

2.2 Individual project: project-based learning (PBL)

There is no shortage of examples of successfully applied PBL in higher education (Guo et al., 2020; Kokotsaki et al., 2016; Perrenet et al., 2000). PBL was selected therefore as the second method for making the BYGA2022 course more practical. It was done by implementing an individual project into the curriculum as an obligatory assignment for students. The goal was that project will make it possible for students to go through the design process from start to finish on their own. One of the reasons why students often fail to relate theory to practice is that they are unable to see the "bigger picture" – they do not understand knowledge and skills they learn are connected and used in practice. It was believed that such a design of PBL could solve that problem. The project required the use of expertise in many topics that were taught separately during lectures, including the use of Eurocodes, calculation and application of loads, creating load combinations, modeling of structure, and use of engineering software as well as finding designing values of forces, moments, displacements, etc.

The project was parametrized with regard to geometry and external loads to ensure that each of the students will be designing a slightly different and unique structure. Figure 3 shows the base concept of the project with parameters depicted by letters/characters. The full project description can be found in the attachments.

Figure 3: The base concept of the individual project that students had to deliver.



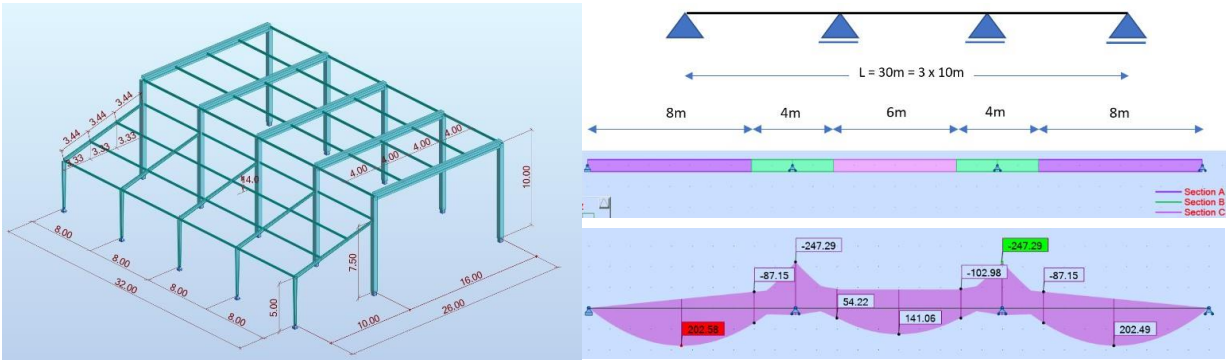
2.3 Software

Students in BYGA2022 learn the basics of mechanics already during their first year of study, so it is safe to assume that they can find bending moments, shear forces, and displacements for simple structures at this point. However, they are not able to get such results for more complicated structures, especially in the case of what we call in civil engineering statically undetermined systems. This limits their ability to contribute to real-life projects. Industry deals with that issue by replacing complicated and time-consuming hand calculations with the use of Finite Element (FE) software. Nevertheless, the use of FE software was not covered so far as part of the civil engineering study program at NTNU at the bachelor level. This is a bit unfortunate for students, since as pointed out by Efeoglu and Gerek (2015), software skills take the lion's share of skills required by employers (Efeoglu, I.E. and Gerek, 2015). Therefore, teaching practical use of such software was considered in this project to be highly beneficial for students' future careers.

Although one can argue that software should not be used without studying how the finite element method works, in reality, the students often try to learn how to use it anyway on their own during their final year to use it in their theses, and very often, making all sort of mistakes during that process. Therefore, the author believes that teaching a minimal amount of theory and focusing on practicality as well as understanding the effects of taken decisions/assumptions in the FE model is still a much better approach than leaving students without any introduction to FE software.

The Robot Structural Analysis (RSA) by Autodesk was selected as FE software in this project. The author has his preferences when it comes to available software after working several years in the industry, however here the decision was supported by the fact that students have already been familiar with Autodesk software, Robot has a low-entry threshold and is directed toward the construction industry. Finally, it is completely free to use for civil engineering students. Students worked on RSA tasks individually using short guidelines on how to complete the task prepared by the educator. Some examples of student assignments in RSA are shown in Figure 4.

Figure 4: Two exemplary Robot exercises: a model of the workshop and envelope of bending moment for 3span bridge.



3 Results

3.1 Feedback from student representatives/reference group

NTNU has a robust system for course evaluation, where reference groups play a crucial role in quality assurance in education. The reference group that consists of a subset of the course's students should have an ongoing dialogue with other students throughout the semester to evaluate the course and write a report at the end of the semester focusing on the constructive feedback with regards to learning outcomes, learning activities and suggestions for changes that might help students achieve better results next year.

The reference group in BYGA2022 consisted of two students and there were a total of three meetings with the course administrator during the spring semester of 2022. Below are translated parts of the report that were considered to provide valuable input into how students perceived new course content. The full report in the Norwegian language is available through the NTNU website.

1. The learning environment has been good and the students got to know the subject's theoretical and practical side.
2. Lectures and other learning activities were diversified. They consisted of both a review of theory, but also practical tasks that were solved jointly or individually as well as exercises solved with the use of software or on the whiteboard.
3. The project was very beneficial and allowed students to review/go through the entire syllabus in a practical and theoretical way. The project has been very instructive and guidance along the way was appreciated. We would like the project to continue for future students.
4. The project work could be launched sooner next time as it requires a lot of time.

3.2 Anonymous survey

Independently from the work of the reference group a separate survey that would investigate students' satisfaction and how they experienced the course content was created. The survey was anonymous and consisted of a total of 20 questions. The participation rate was 48% what can be attributed to the fact that the survey was voluntary and conducted after the teaching period (but still before the exam). Questions were related to how students perceived different teaching activities and the course's usefulness during the spring 2022 semester. Selected results from the survey are presented in Table 1 and Table 2. 10 from the total of 21 students participated in the survey.

Table 1: Survey results on the question: How satisfied/dissatisfied are you with the following part of the course?

	Satisfied	Slightly satisfied	Neither/nor	Slightly dissatisfied	Dissatisfied
Individual project	90 %	0 %	10 %	0 %	0 %
Feedback from the lecturer	100 %	0 %	0 %	0 %	0 %
Part of the lectures in English	90 %	10 %	0 %	0 %	0 %
Exercises with software	80 %	10 %	10 %	0 %	0 %
Mandatory assignment	80 %	0 %	20 %	0 %	0 %
Communication with the lecturer	90 %	10 %	0 %	0 %	0 %

Table 2: Survey results on the question: How much do you agree or disagree with the following statements about the course?

	Strongly agree	Fairly agree	Neither/nor	Fairly disagree	Strongly disagree
I believe that the skills I acquired during the course will be useful in my future career	70 %	30 %	0 %	0 %	0 %
It is very likely that I will recommend BYGA2022 to a colleague	70 %	20 %	10 %	0 %	0 %
It is important for me to look at examples from industry / working life	90 %	10 %	0 %	0 %	0 %
It was useful to have an introduction to Robot Structural Analysis	100 %	0 %	0 %	0 %	0 %
BYGA2022 was a demanding course	10 %	60 %	20 %	10 %	0 %
It was useful to have some of the lectures in English	40 %	50 %	10 %	0 %	0 %
It was difficult to follow the lectures in English	10 %	0 %	20 %	50 %	20 %

It can be seen from Table 1 that the vast majority of course participants were satisfied with new teaching activities including individual projects, lecturing in English, new exercises, and assignments with engineering software. The majority also believe that the skills they acquired in the course will be useful in their future careers – see Table 2. Communication and feedback from the lecturer scored also very high in the survey. Those marks are especially valuable and satisfactory for the author as there is always a risk that despite all the good intentions, a poorly designed course will confuse the students rather than provide improved learning outcomes. It is an issue that every course coordinator must account for when planning curriculum revision. As there were a lot of new tasks for students they are not used to, it was essential to put more work into supervision and guidance, such that the teaching activities will be still demanding and challenging but not frustrating or understandable. In the case of BYGA2022, it was achieved by:

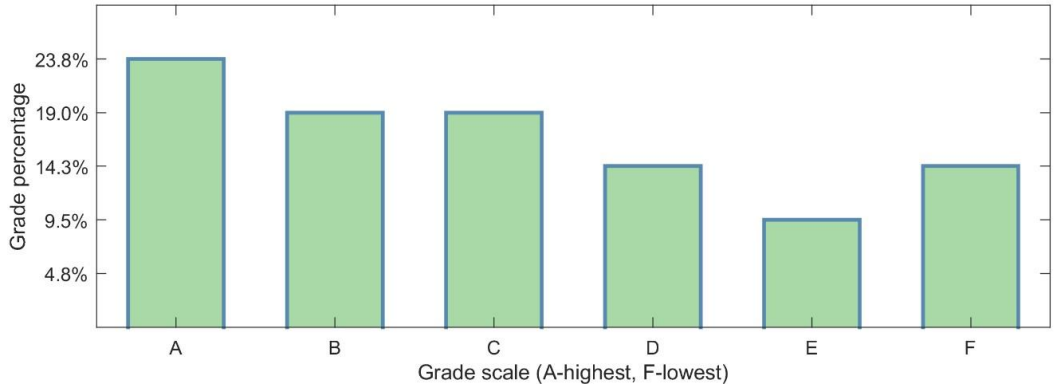
- Keeping an open dialogue with the reference group.
- Posting additional examples on Blackboard which is NTNU online teaching platform, when necessary.
- Preparing small guidelines for new tasks, such that students can follow instructions when stuck.
- Closely supervising individual projects, controlling students' progress, and identifying possible areas/topics that need more explanation.
- Providing personalized comments on project results.
- Prioritizing response time for students' emails.

Described above actions put some strain on the lecturer, however, as long as the group of students is relatively small it is possible to handle additional tasks without the need for student assistants. All in all, students evaluated the course mostly as fairly demanding which is the sweet spot the author was aiming for.

3.3 Examination results

Finally, the learning outcomes can be also evaluated using exam results. One must be careful doing that, however, since still grade distribution is highly dependent on individual matters, student background, studying environment and many others. The exam itself looked also completely different compared to previous years and tasks/questions were much more difficult, oriented towards solving practical problems as well as curriculum size increased. To make sure that students can handle such a challenge and prepare themselves better, it was decided to create an additional exam set, that was solved by the lecturer during the last lecture. The final grade distribution based on exam results is shown in Figure 5.

Figure 4: Distribution of final grades in the BYGA2022 course



4 Results and discussion

Firstly, based on meetings and final rapport from the student reference group, it can be deduced that students evaluated the course positively from both theoretical and practical sides. They noticed and appreciated that learning activities were diversified as well as practical. Especially positive feedback concerned the project that students had to solve individually and the guidance they received during working on it. Students claimed that the project allowed them to use theoretical knowledge in practice and recommended continuing with the project work in the future. Secondly, presented in chapter 3.2 survey shows a great level of satisfaction with various, new course activities among the students, which gives the author of the paper a confirmation that implementing the described herein practical learning approach was something that improved the studying experience. It should be emphasized that most students evaluated the course as fairly challenging but not to the point where they would feel overwhelmed. Thirdly, it was very satisfying and rewarding to see that the majority of the course participants were able to solve exam tasks with many students getting an A – the highest possible grade, something that possibly reveals student engagement.

Finally, the effectiveness of the implemented changes to the BYGA2002 can be also evaluated by looking directly at the overall score assigned by students. The course scored 4.56 on average in student evaluation with 5 and 1 being respectively the highest and lowest scores. This is much higher than the average course evaluation at NTNU. Although the author tried so far not to provide his opinions/feelings about course outcomes, he would like to add a couple of comments. Most of the students were visibly engaged during the course, solved problems and assignments with curiosity/interest, and asked a lot of valuable questions. It can be said that participants in BYGA2022 were able to cope very well with provided

tasks/assignments and in addition, reacted positively to new challenges. Many of the delivered projects were of excellent quality and the author was impressed by how fast students become comfortable with using new software.

5 Conclusion

In this paper, results from the modification of the BYGA2022 course have been presented. The assumption was that through the implementation of a more practical learning approach, namely using cases-studies, implementation of the individual project, and education of engineering software, lectures and course assignments will become more engaging resulting in a better understanding of challenges faced daily by structural engineers among course participants. This assumption was examined using feedback from student representatives, an anonymous survey, and final examination results.

Overall, the modernization of the BYGA2022 course described in this paper is considered to be a success. Students reacted positively to new course content and have seen positive value arising from considering real-life examples. The individual project was very well received and considered to be extremely useful as it allowed them to combine theoretical knowledge with practice. However, it provided also a lot of extra workload. Therefore, reorganizing the individual project such that the workload can be disturbed more equally during the semester is something that needs to be addressed in the future.

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References

Arlett, C., Lamb, F., Dales, R., Willis, L., and Hurdle, E. (2010). Meeting the needs of industry: The drivers for change in engineering education, *Engineering Education*, 5(2), pp. 18–25.

Audu, R., Kamin, Y. Bin, Musta'Amal, A. H. Bin, & Saud, M. S. Bin. (2014). Assessment of the teaching methods that influence the acquisition of practical skills, *Asian Social Science*, 10(21), pp. 35–41.

Chinowsky, P. S., & Robinson, J. (1997). Enhancing Civil Engineering Education Through Case Studies, *Journal of Engineering Education*, 86(1), pp. 45–49.

Efeoglu, I.E. and Gerek, I. H. (2015). What Qualifications and Skills Are Important for Civil Engineers? a Job Advertisement Analysis. *Proceedings of Managing Intellectual Capital and Innovation for Sustainable and Inclusive Society in Bari*, pp. 689–695.

Evans, D. L., Beakley, G. C., Crouch, P. E., and Yamaguchi, G. T. (1993). Attributes of Engineering Graduates and Their Impact on Curriculum Design, *European Journal of Engineering Education*, 82(4), pp. 203–211.

Grabmukkerova, A. (2017). Students welcome a more practical approach to teaching, including real cases. Panorama Nettavis. https://panorama.himolde.no/2017/10/26/studentswelcome-a-more-practical-approach-to-teaching-including-real-cases/

Guo, P., Saab, N., Post, L. S., and Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures, *International Journal of Educational Research*, 102, 101586.

Kokotsaki, D., Menzies, V., and Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, 19(3), pp. 267–277.

López-Querol, S., Sánchez-Cambronero, S., Rivas, A., and Garmendia, M. (2015). Improving civil engineering education: Transportation geotechnics taught through project-based learning methodologies, *Journal of Professional Issues in Engineering Education and Practice*, 141(1), 01044007.

Moore, T. J., Glancy, A. W., Tank, K. M., Kersten, J. A., Smith, K. A., and Stohlmann, M. S. (2014). A Framework for Quality K-12 Engineering Education: Research and Development. *Journal of Pre-College Engineering Education Research*, 4(1).

Nehdi, M. (2001). Crisis of civil engineering education in information technology age: Analysis and prospects, *Proceedings of 31st Frontiers in Education Conference in Reno*.

Perrenet, J. C., Bouhuijs, P. A. J., and Smits, J. G. M. M. (2000). The Suitability of Problembased Learning for Engineering Education: Theory and practice, *Teaching in Higher Education*, 5(3), pp. 345–358.

Ruiz-Teran, A. M., and Aparicio, A. C. (2007). Tradition and Innovation in Teaching Structural Design in Civil Engineering, *Journal of Professional Issues in Engineering Education and Practice*, 133(4), pp. 340–349.

Scott, G., and Yates, K. W. (2002). Using successful graduates to improve the quality of undergraduate engineering programmes, *European Journal of Engineering Education*, 27(4), pp. 363–378.

Shaaban, K. (2013). Practical teaching and its importance in teaching civil engineering. *QScience Proceedings of Global Innovators Conference 2013 in Qatar*.

Shi, D. (2014). Improving the practical ability of civil engineering students. *World Transactions on Engineering and Technology Education*, 12(1), pp. 111–115.

Shiferaw, H. M. (2022). Evaluating practical teaching approach in civil engineering training among public universities of Ethiopia: students' view and opinion, *African Journal of Science, Technology, Innovation and Development*, 14(1), pp. 216–224.