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# Experience of Project-Based Learning for First-Year Engineering Students at GMIT

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***Abstract*-- This study introduces the experience of a project-based learning (PBL) approach for first-year engineering students at German-Mongolian Institute for Resources and Technology (GMIT), Mongolia. The engineering project course at GMIT is the first-ever PBL experience for engineering curriculum in Mongolia and adapted from the engineering program at the Technical University of Darmstadt and has been implemented since 2014. It is dedicated to preparing students for gaining both technical and soft skills through PBL from the beginning of their engineering education. The questionnaire surveys are taken regularly during the course period from students to improve the course quality. The current study presents the analysis of questionnaire surveys done in 2019 and discusses the benefits and challenges of the course. The responses by students revealed that the implementation of the course was beneficial in improving teamwork. Suggestions based on the PBL are given to improve the effectiveness of engineering education in Mongolia.**

***Keywords- project-based learning experience, first-year engineering project, German engineering program, GMIT.***

## I. INTRODUCTION

Project work is necessary for the workplace in the field of engineering and engineering students are necessary to obtain both technical and soft skills during their study years to become successful professionals. PBL is a particular type of learning where learners are actively involved in the learning process while learning the course content through collaboration and sharing of knowledge and experience ([5] [6][15][11][7][12]) to achieve a shared goal. Application of this method shows remarkable changes in students' learning environment as they expect to be more active participants in the learning process, involved in developing soft skills such as teamwork, presenting their work, confidence in the new team, responsibility, and time management, etc..

German-Mongolian Institute for Resources and Technology (GMIT), the youngest state-owned university, was founded in 2013. The GMIT aims to prepare highly qualified, socially responsible, internationally recognized and creative engineers by international standards and experience ([20]). Thus, the curriculum is designed and supported by German partner universities with contributions from the German Agency for International Cooperation (GIZ) and the German Academic Exchange Service (DAAD). Students have the same curriculum for the first 1.5 years, then specialize in raw material process, mechanical, environmental, electrical, industrial, and mechatronics engineering.

PBL in engineering programs is applied in higher education institutes in many countries ([17][13][17]). The meaningful learning approach has been adopted from German engineering education practice at the GMIT since 2014 ([17]). In order to improve the didactic and administration tactics, daily surveys have been taken among the first-year engineering students each year during the course. Such surveys are commonly used in the engineering PBL courses ([1]). This study introduces the experience of PBL at the GMIT, the only higher education institute, that applies the first-year engineering project in Mongolia, to the authors' knowledge. Moreover, the results of the surveys taken among the first-year engineering students, who participated in the regular engineering project, are introduced in the current study. In addition, based on the experiences seen at the GMIT, the current study provides suggestions to further improve the engineering curricula in Mongolia.

Section II provides a theoretical background of the PBL, a German engineering project, and survey results as a part of the engineering project course. Sections III and IV provide the brief report on implementation of the engineering project course at the GMIT and survey analysis for 2019 taken from students. Discussion, Conclusions, and recommendations based on the experiences at the GMIT and survey evaluation are given in Sections V and VI.

## II. BACKGROUND OF THE DIDACTIC METHOD

The PBL design occurred early 1970s at McCaster University in Canada, when students excited obtaining their skills while practicing in a real-life (Barrows, 2000). The concept of the PBL is that the learning moved out of the classroom and occurred in a real-life. Initially, the implementation of PBL has spread widely in medical education, but has spread later in the spheres of law and engineering education. As the engineering graduates require many soft skills, the increasing interest in PBL is gained in the engineering education. The earliest implementation of

PBL for a first-year engineering students was introduced by Rubino in 1998 ([19]). The concept was implemented and improved in various engineering education in many universities (ex., [8][9][14]). As the name indicates, PBL is a teacher facilitated, student centered method of teaching, which starts with a comprehensive real-world problem to be collaboratively solved by team members. Under the guidance of advisor teachers, students learn how to productively communicate, collaborate, and work on a team, while creating new ideas to tackle daily sub goals which lead to master complex tasks at the end of the week. The expectation, that each team member will contribute equally to the daily progress, improves the peer accountability and the daily goal setting including short meetings, promotes the time management. It is quite often that, task driven and motivated students, grab more challenging literature or online material, which extend their technological knowledge. Daily surveys help the freshmen to improve their self-evaluation skills..

## III. DEVELOPMENT OF THE GERMAN ENGINEERING PROJECT

The Technical University of Darmstadt developed an engineering course entitled "Introduction to Mechanical Engineering" in 1998 with the purpose to advance active and collaborative learning techniques ([10]). Certain methodological approaches and didactic concepts are well-designed and adopted ([17]). First-year students are divided into teams and have one week to solve an engineering problem. Support facilities such as a support team, help-desk, and professors, are offered to student teams for effective results. The course became an essential element in the curriculum and was later adopted in South Dacota School of Mines and Technology and Virginia Tech, United States, and GMIT, Mongolia ([17]). The results of the comparison between course-participants and non-participants at the Technical University of Darmstadt showed clear differences in dropout rate and further success in their studies.

The first-year engineering project offers an elaborated didactic concept ([10][4]). The course is held at the beginning or right after the first semester of the first-year bachelor's study for a whole week. Participation in this course is obligatory for all first-year students at the GMIT. The course becomes the first-ever PBL course in the engineering curriculum in Mongolia. An interdisciplinary, comprehensive engineering problem is given to students. The problem should be challenging, sufficiently complex, motivating, and not too difficult or easy for students. Professors (up to 3) and team assistants, and expert advisors are involved in this course activity. Information regarding their roles is given below:

– Professors: search and select an adequate engineering problem, give an introduction to the problem and have to assign tasks to students. Students discuss their problems and solutions with professors as needed.

– Team assistants: consist of lecturers and assistant lecturers. They assist the team in the development of teamwork, supervise the methodology of research, and supervise in general.

– Expert advisors: Consultation provides information and relevant material to teams. They are available once at certain hours when the teams become familiar with a given problem. Experts and assistants take roles in providing general/indirect replies to students' specific questions since one of the goals of the course are to develop the self-learning skills of learners.

– Student teams: An engineering project course is done in teams. A team consists of 7-10 students usually. A team leader is appointed among the team and this role is sequenced every day so that half of the students have the possibility to take the responsibility for leading the team. A teamwork ability is important to achieve successful results. The concept of the course is each team member contributes to teamwork and advances the communicative, cooperative, social mindset, responsibility, creativity, leadership, problem-solving skills, respect for others as well as professional knowledge. Since the choice and autonomy on solutions are given to students, the students are likely to be less productive than in traditional classroom learning (teacher-centered), thus in order for students to work productively, the team assistants provide them with the tools to direct the appropriate direction.

– Evaluators: Evaluation of presentations is done by an odd number of professors and experts at the end of the final presentations. Team effectiveness is assessed by presentation content (overview, critical concepts, understanding of technical issues, organization and flow, solutions, summary, Q&A), presentation delivery (visual aids, time management, presentation), poster, and final report.

During the course, a preliminary presentation is shown internally in a team to professors to properly develop the content of the final presentation. On the last day of the class the teams should deliver a written report, a poster and a presentation, where other students, faculty members, and others who are interested can attend the final presentations of the teams. Based on the evaluation, the team with the highest score is announced and appreciated.

The important factors of a successful project are interdisciplinary project tasks, sophisticated logistics, a project team including professors, team assistants, and expert advisors, and an operational plan including surveys. To improve the practice, a project team conducts surveys.

Fig. 1. Teamwork during the engineering project course

**Survey:** To effectively organize the daily activities and further consideration for the development of the course, the following two types of questionnaire surveys are collected from the students daily and once after the project period, and the surveys are systematically evaluated internally within project team for the effectiveness of course instructors and feedback.

1) Routine survey. This survey is collected from each student every day after class hours. The survey questions may differ from day to day. This routine survey is about managing routine tactics for the project teams to effectively coordinate activities on the following days. Professors and assistants benefit from this survey as well.

2) Final survey. This refers to the evaluation of the whole project. The idea is to find out the necessary improvements that we can implement for the next year. The surveys used to be paper-based before 2019, and they have been conducted online since then.

The current study presents the analysis of the survey taken in 2019.

## IV. RESULTS

**Experience of implementation of the PBL at GMIT.** The interdisciplinary, a German engineering project has been implemented at GMIT since 2014. It became a part of the engineering study curriculum and the first-ever experience in the project-based course for first-year engineering students in Mongolia, to the authors' knowledge. The course was developed by Prof. Dr. Manfred Hampe and designed for Mongolian conditions – more attention was paid on teamwork and team management. Table I shows the topics of the course chosen over the past years and the number of students who have participated in the project.

Table 1. Details of the first-year engineering projects at GMIT

| Study Year | Number of students | Engineering problems |
|---|---|---|
| 2014/2015 | 23 | Design a system that is capable of collecting and sorting litter along the roadside or on beaches, and that which also might be used to sort waste materials at municipal landfills. |
| 2015/2016 | 16 | Renewable energy solutions for greenhouses in Mongolia |
| 2016/2017 | 27 | Develop a solution to remove NOx from the exhaust gas of diesel engine automobiles using UREA |
| 2017/2018 | 25 | Propose a solution to improve air pollution in Ulaanbaatar |
| 2018/2019 | 45 | Design a project model that should make "Nalaikh's abandoned mining site" profitable |
| 2019/2020 | 58 | Design a cost-effective winter greenhouse for GMIT |
| 2020/2021 | 64 | Solutions to Ulaanbaatar city's air pollution: coal briquettes |
| 2021/2022 | 84 | Propose a plant that is capable of generating energy by incinerating waste in Ulaanbaatar |

Students work in teams, make decisions as a team, set network with teammates, professors, and experts through efficient communication and problem-solving. To evaluate the satisfaction of the students, the survey by the students showed that the module evaluation reaches the point of 4.36 out of 5. This means, the overall satisfaction of the students regarding the module scores is above 85 percent. Besides the first-year engineering project course, its successor course "Final Study Project" for the senior students has been implemented at GMIT. Thus, these two courses are the examples of implementation of the PBL for the engineering students at GMIT in Mongolia.

**Survey evaluation.** To improve the quality of the project-based course, the questionnaire was collected from all participating students each year. The surveys are taken from each student every day after class hours during the course. Thus, the sample size is the same as the number of students (see Table 1). As an example, the routine survey of 2018/2019 is analyzed in this paper and some results are presented in this section. A total of up to five questions were asked to students. Students were divided into 5 teams and teams are numbered from 1 to 5. In order to help students effectively time-manage along with project schedules, better group work quality, planning for the next day and so on, the following question was asked every day: How do you evaluate the progress made by your team today? Responses to the survey question on Day 1 and Day 2 by two teams are shown in Figure 2. 9 students responded from each team, respectively.

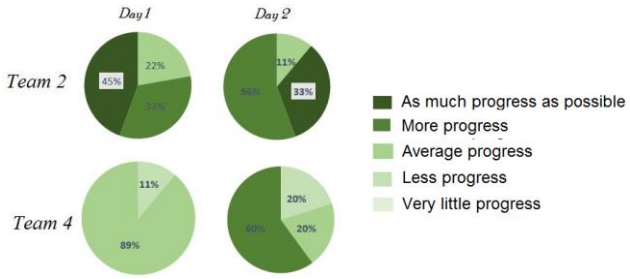


Fig. 2. Responses to the routine survey question

After the first day of the course, Team 4 was not satisfied with the team's progress in general. A majority of the members (89%) claimed that they made average progress. Thus, based on the survey responses, the assistants and professors decided to focus more on team building and gave extended guidance and tips on collaboration specifically within Team 4 starting on the second day. After the second day, Team 4 made improvements ("More progress" from 0% to 60%). In comparison, Team 2 was satisfied with their progress and stayed very similar but with better improvement in "More progress" throughout the first two days. Thus, the team requires less involvement of teacher intervention. In addition to the routine progress day by day, the questionnaire also asked students how satisfied they were with team-building activities, if other problems kept students from contributing more, etc.

One of the key objectives of the course is to improve communication between students. In 2019, 44 students participated in the final survey and 75% of them claimed that they preferred working in teams, and almost 23% of them found that it was quite hard to work with their teammates. In this case, there was another question: "Do you feel underappreciated by your team members?", to which 27% of the students answered "Yes".

Another key aspect of the course is to give first-year students a taste of engineering design. According to the same survey, more than half of the students liked the research and design part of the project. Such a response seems encouraging if we recall that the students conducted research and design on their own during their high school years. Apparently and as expected, the engineering project course for the first-year

engineering students was their first experience with PBL. Most of these students valued the experience gained from the course, according to the responses in the free commenting section. However, one-third of the participants found the design and research part hard and tedious. To find the reason behind the difficulties we include open-ended questions and free commenting possibilities in our survey. A majority of the students commented that time management was the hardest. It was expected by assistants and professors as the students are in their first year of bachelor's study.

Based on the survey analysis and experience gained over the years, it was found that PBL contributes to the improvement of several soft skills such as teamwork, problem-solving, cooperative learning, management, etc.

## V. DISCUSSION

Experience of the PBL approach at the GMIT reveals benefits to students to improve their "learning by doing". Survey analysis showed that the team working skills had progressed during the course. In general, there can be identified over 30 distinct advantages of PBL ([15]) and experience of the PBL approach, a first-year engineering project course, at the GMIT shows several significant benefits but is not limited to:

– Students are more encouraged and engaged in collaboration, organizational, management, and planning skills. This enhances communication skills, cooperative learning, and personal autonomy as well. For example, students get chances to present and defend their ideas and thoughts to teams. In addition, it promotes students' self-learning, professional discipline, and responsibility to peers.

– The approach makes the best for students in performing projects through mastering methodology: understanding the nature of the problem, finding information, brainstorming, problem-solving, presentation and reporting skills, etc.

– Experience to encounter and solve real-world engineering problems: role distribution such as investigation of the problem, calculation, and finding solutions. This enhances motivation and interest in further study and professional work.

It was revealed that the disadvantages of PBL are less numerous than the advantages ([15]). Several disadvantages or challenges in the engineering project course encountered at the GMIT can be:

– Language barrier: Since the official language at the GMIT is English, students are required to communicate in English. When the student's language skill is not sufficient, the student is more likely to feel not included in the team and stay away from the teamwork.

– Some students take over various roles and overload themselves with work, which worsens their productivity. This originates from poor management and a lack of experience in active learning.

– Students have to manage the distribution of the workload within the team themselves. We often observe that the misdistribution of tasks within the team leads to difficulties to keep the schedule and delays further steps. The tasks are completed at different times, some students finish early or take longer than others. Thus, some students may feel dis-engaged in the team. To assistants' and professors' observations over the past years, in such cases, students start to realize their mis-attempt in organizations on the third day of the course. The tasks should be distributed based on students' abilities while planning the intra-team dynamics.

PBL at the GMIT has been implemented in different contexts and phases ranging from the first semester to the final semester of the bachelor's study years. The latter is carried out in the form of a Final Study Project, where the students conduct a more comprehensive, science-based project while engaging in specific advanced engineering tasks and developing and documenting the whole engineering process towards interdisciplinary collaboration. The engineering topic is given to students to enable a multi-professional role as a raw material processing, mechanical, environmental, electrical, industrial, or mechatronics engineer. Students tend to achieve encouraging results in the Final study project in the last semester of their bachelor's years compared to the first year of their engineering project.

## VI. CONCLUSION

The implementation of PBL for first-year engineering student at GMIT runs effectively. It offers several benefits in engineering skills, for example team work, problem-solving, self-learning, and presentations skill in learning. Our empirical evidence suggests continuing the traditional long-term surveys and another survey from graduates to evaluate the benefits of PBL on their further studies and professional future. Based on the interdisciplinary engineering project implemented at the GMIT, the first-year engineering project can be facilitated in engineering programs in other higher education institutes in Mongolia.

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