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Exploring The Impact Of Problem-Based Learning On Student Learning Outcomes: Findings From The PBL South Asia Project

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ABSTRACT

This paper presents the results of surveys conducted among students and teachers / mentors in Nepal, Bhutan, and India, regarding the impact of implementing Problem-based learning (PBL) methodology in engineering and multidisciplinary projects. The surveys were carried out under the Erasmus+ funded project, "Strengthening Problem-based learning in South Asian Universities" (PBL South Asia). The project aimed to address the issues of education quality, employability, and sustainable development in the region by enhancing students' practical experience, communication skills, teamwork abilities, as well as academic knowledge through PBL-adapted courses. As a result, South Asian higher education institutions have implemented PBL courses in their curriculum.

The surveys were designed to evaluate how specific competences or learning outcomes were perceived by different stakeholder groups, e.g., which learning outcomes were expected to be achieved by the faculty, and whether they were achieved by students. Several methods were used for the assessment – open questions with tracking the keywords that the respondents use, as well as "EntreComp" framework which looks into how students assess their abilities to be curious and open, think sustainably, behave ethically, and cope with uncertainty and ambiguity.

Results of the survey showed that student participants have identified teamwork, communication and presentation skills as those most associated with PBL methodology. Among the self-assessed improvement in abilities, students have indicated their increased abilities to assess the needs of different stakeholders, combining different contexts, setting up strategies.

1 INTRODUCTION

1.1 PBL methodology in engineering

The role of practicing engineers in promoting sustainability is vital, as their work is closely tied to societal progress. In recent decades, there has been a growing interest in pedagogical approaches that equip students with the competences required to make effective decisions in a rapidly changing world. These approaches frequently link the United Nations' Sustainable Development Goals with learning outcomes and employ constructivist and student-centered methods to contextualize sustainability issues within local, disciplinary, and professional contexts (UNESCO 2017, Rajabifard et. al. 2021) Problem-based learning (PBL) is one of such approaches that has gained attention as a pedagogical strategy capable of providing the necessary learning outcomes to foster a sustainable society (Thomas 2009).

PBL has been widely adopted in engineering education for its potential in developing students' professional skills, motivation and subsequently, their academic performance (Duch et. al. 2001, Acharya et. al. 2021, Acharya et. al. 2021). By the virtue of this learner-centered approach (Savery 2015), engineering students are given opportunities to actively engage with open-ended challenges (Torp and Sage 2002, Hmelo-Silver 2004) through understanding, finding, learning and applying theories in a self-directed and multidisciplinary way. In terms of professional skills, the PBL approach especially facilitates the development of capabilities needed to work in diverse disciplinary contexts requiring collaborative knowledge construction, which is needed both in engineering professional practice and addressing complex challenges (Torp and Sage 2002, Kolmos and Graaff 2015). These skills are essential for future careers as new and upcoming technologies and tools exceedingly create demand for creative and competent engineers capable of solving complex challenges of the society.

Although PBL has gained recognition as an effective teaching method in engineering education, empirical research on its implementation has predominantly been focused on Western contexts. There has been limited research on PBL in regions where traditional, teacher-centered approaches are still prevalent. Additionally, there are few examples of PBL's practical implementation and effectiveness in cross-institutional contexts, particularly in international collaborations. A study on South Asian universities found that present undergraduate engineering education offered is didactic, content-heavy, lacking adequate practical experience and knowledge of real-world sustainability issues and impact, as well as industry-ready competences (Acharya et. al. 2021). The current undergraduate engineering education scenario – at the regional and local level, through secondary and primary research, highlights the policies and challenges in the face of implementation of the same, due to varied structure of autonomy, as well as resource availability. These are big constraints, especially in South Asian countries with similar institutional contexts such as India, Nepal and Bhutan. The engineering education and curriculum development is usually overseen by the national level body on technical education (e.g. All India Council for Technical Education – AICTE in India; Nepal Engineering Council – NEC). The engineering courses are offered on university campuses or in affiliated colleges. While the independent university campuses enjoy a

relatively greater freedom in designing and execution of curriculum for engineering courses (based on broad guidelines from the national bodies), the affiliated colleges are constrained to use the syllabus prescribed by the university to which they are affiliated. Furthermore, the evaluation schemes vary differently between deemed universities. The university-based engineering courses have greater flexibility in assessment schemes, whereas the affiliated colleges are more restricted to follow the guidelines for the universities. The assessment is usually done by a common exam across all affiliated colleges within a university. Thus, the teaching in colleges are geared toward preparing the students for these common examinations, rather than preparing them in solving real-life, 'wicked' problems.

Against this background, this paper reports the impact of a cross-institutional and multidisciplinary PBL methodology on students, teachers and faculty from South Asian and European HEIs.

1.2 Case study: PBL South Asia project

The PBL South Asia project, a joint initiative among ten universities from India, Nepal, Bhutan, Finland, the Netherlands, and Lithuania, was co-funded by the Erasmus+ Programme and led by Aalto University, Finland. The project ran from 15.11.2018 to 14.11.2022 aiming to develop curricula and teaching competence in PBL for global sustainability themes, particularly in the technical field, to enhance critical thinking, innovation capacity, professional skills, and employability among students in intercultural and regional contexts in South Asia. During the project, six partner HEIs from Nepal, India, and Bhutan developed and implemented PBL-based curricula. All HEIs engaged in co-creation of educational content, practices and intercultural engagement around PBL methods application in courses offered to diploma, undergraduate, and graduate students among partner HEIs. The project developed practical teaching competences, transitioning from traditional to student-led learning in the region. It facilitated iterative student-led challenges and interdisciplinary group work, independently and as a component of newly adapted PBL curricula, bridging teacher training in action with peer teaching activities among the consortium members. This approach also encouraged increased engagement between academia and local societal and innovation ecosystem partners to address complex local and global sustainability challenges, while building skills and knowledge among participating students, mentors, and course coordinators.

PBL is no new invention, yet its application in multicultural, multidisciplinary and deeply heterogeneous HEI settings with advanced and beginner levels of PBL adoption is an unusual approach as implemented in the project. It called for a culturally adjusted reinterpretation of normative sustainability agendas, an encounter of entirely different realms of competence, a format in which teachers take the supportive role in facilitation and students take the lead role in learning, balancing and navigating hierarchies and cultural barriers, to develop novel international practices for inclusive PBL education. Project HEIs were organised into three groups: European Programme HEIs, Nepal and Bhutan HEIs aiming for PBL integration and Indian HEIs aiming for

best practices development in regional applications of PBL education and teacher training. Activities were mostly based in South Asia, due to the assumption that educational content development needs to take place in the context where it will be rolled out, ensuring actionable changes and locally appropriate modalities. It was also evident that the experienced universities did not have advanced knowledge of teaching circumstances at South Asian HEIs.

Despite serious disruptions to project implementation by the Covid-19 pandemic, the main results and overall impact were achieved. The results include but are not limited to, the introduction of PBL via adapted curricula in Nepal and Bhutan, best practices and teacher training development in India and Europe, a series of international and local student projects, significant institutional engagement and dissemination at consortium HEIs on PBL education, an internationally cocreated MOOC course and modules, follow-up projects and networks.

2 METHODOLOGY

The PBL courses were created or updated in South Asian partner HEIs. Main competences that the new and updated courses are addressing: transversal, behavioural skills, technical, academic, scientific and research skills, linguistic competences, group work skills, interpersonal skills, and learning by doing in the real-world scenario skills.

Before the PBL South Asia project, most of the HEI's in South Asia did not offer PBL courses and most of the teachers/mentors also were not trained in PBL methods. In order to assess the benefits of the PBL questionnaires were designed for students, mentors/teachers, and faculty to be filled in both before and after the PBL courses and distributed online. The surveys were designed to evaluate how specific competences or learning outcomes were perceived by different stakeholder groups, e.g., which learning outcomes were expected to be achieved by the faculty, and whether they were achieved by students. The surveys also investigated PBL practices – the methods used in the courses, the organisation of the teaching/learning process, the logistics, management change, etc. The methodology of questionnaires crosscheck is presented in Fig.1.

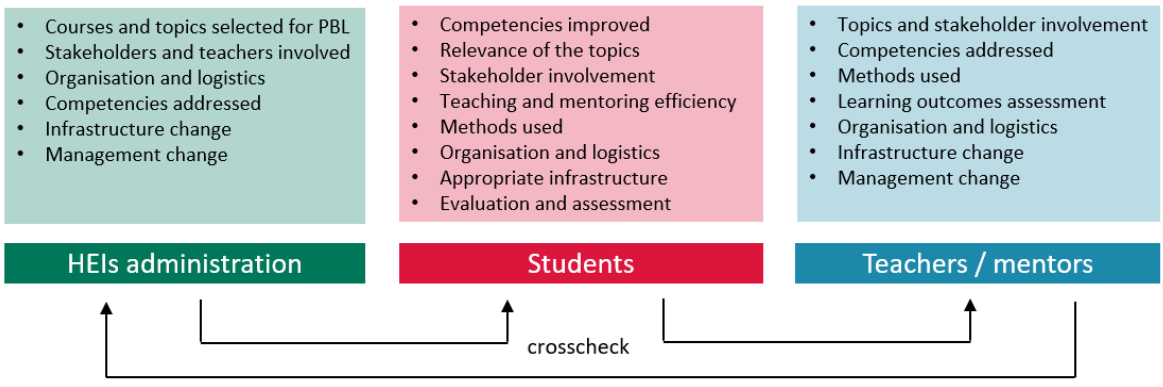

Fig. 1. The PBL SA Methodology of Questionnaires Crosscheck

Two sets of questions were included in the survey – the first set of questions was looking into the overall satisfaction with the PBL courses and understanding of PBL methodology, including the open questions which were used for keyword extraction, as well as collecting the data on the competences increased. The second set of questions was based on the “EntreComp” framework (McCallum et. al. 2020) and investigated behavioural patterns and skills, namely – how students assess their abilities to be curious and open, think sustainably, behave ethically, and cope with uncertainty and ambiguity. The feedback gathered from students’ questionnaires is collected from the updated courses, and thus also reflects the experiences students have had in these various local or international real-life case studies.

A selection of the EntreComp framework was used for the PBL courses evaluation as there is an overlap of competences being addressed in PBL education and entrepreneurship education. The EntreComp framework is a tool designed by a consortium of researchers and funded by the European Union to support the development and understanding of entrepreneurship competences. The framework includes a range of fifteen entrepreneurship-related competences, divided into three main categories: ‘Ideas and Opportunities’, ‘Resources’, and ‘Into Action’. It is designed to be used in entrepreneurship education programs to help students develop their entrepreneurial skills and knowledge.

The first category, Ideas and Opportunities, includes five competences that relate to the identification and evaluation of business ideas. The competences for this category are: Creative thinking, Opportunity identification, Vision, Valuing ideas and taking calculated risks, and Ethical and sustainable thinking. The second category, Resources, includes six competences that relate to the management and utilization of resources to create and run a successful business. These competences are: Mobilizing resources, Financial and economic literacy, Taking the initiative, Planning and management, Coping with uncertainty, and Learning through experience. The third category, Into Action, includes four competences that relate to the implementation of business ideas and the management of a growing enterprise. These competences are: Mobilizing others, Communication and persuasion, Self-awareness and self-efficacy, and Initiative and perseverance.

The total number of students’ responses received before the course was 75. However, approximately 25% of students did not complete the survey after the courses. Nevertheless, this is quite typical in the academic setting, and the participants were only invited to submit their responses twice, in order to avoid random or careless responses just for the sake of responding. The number of mentors who filled in the survey before and after the PBL course was 15 and 14 respectively.

3 RESULTS

Before integrating PBL into South Asian HEIs, questionnaires were given to the administrative staff / managers of South Asian HEIs. The objective was to identify the expectations held by the HEIs regarding the skills and competences that students would enhance through the adoption of PBL. Since only one response per institution

was collected for the survey, the detailed findings are not presented in this paper. However, there was a consensus among the respondents, and the expectations of the HEIs revolved around embracing new pedagogical approaches, fostering active learning, producing industry-ready graduates, enhancing problem-solving abilities, improving communication skills, and developing a better understanding of the complex and multidisciplinary aspects of their respective professions.

The results of the students and teachers / mentors responses are presented in Fig. 2.

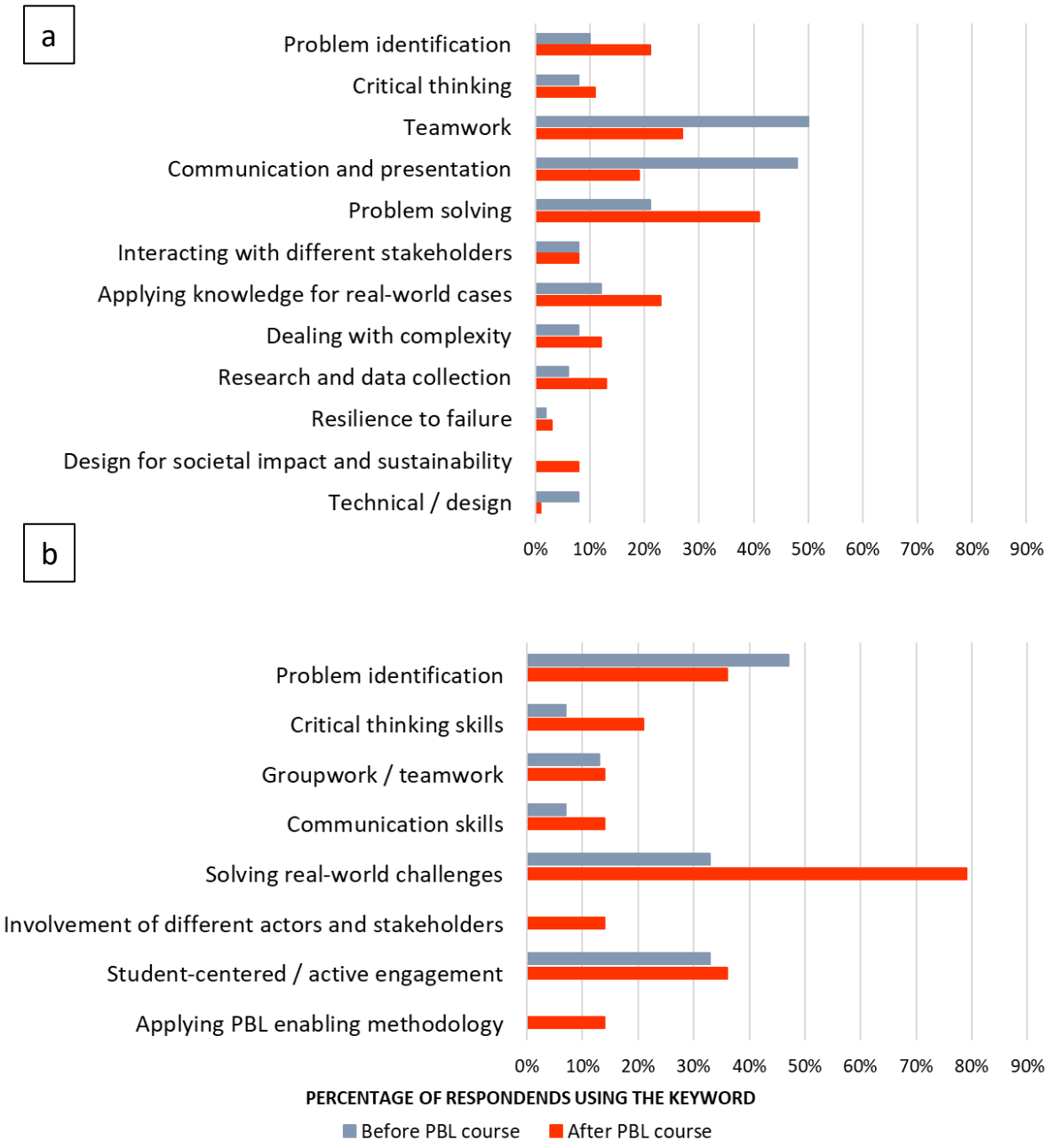

Fig. 2. The appearance of selected keywords in the responses of students (a) and teachers / mentors (b)

The results of the students' responses showed that students perceived the concept of PBL differently before and after the course. As it was mentioned before, open questions were provided for students, where they could write their associations and

statements. The chosen keywords indicated how students' perceptions changed before and after the PBL courses. Keywords analysis showed that most of the students extracted these competences obtained after PBL courses: improved technical / design skills; improved teamwork skills; developed skills in communicating with stakeholders; developed communication and presentation skills; built confidence in speaking and listening; improved leadership skills. Keywords analysis also showed that PBL courses had a significant impact on the competences of students.

Analysis of students' responses to the "EntreComp" framework survey showed that students have increased the ability to identify challenges after the PBL courses; they also improved their teamwork skills and their ability to deal with complexity. Keywords analysis and responses to the "EntreComp" framework survey demonstrated that the PBL methodology that was used in the new courses had a positive impact.

Based on the results of the received students' responses, it can be observed that HEIs expectations, which were raised before the PBL courses, have been implemented. Students improved their communication skills along with teamwork and leadership skills. However, it is noteworthy that, after PBL course, students mentioned "Teamwork", "Communication and presentation" keywords less frequently. Instead, they emphasized other aspects of PBL, such as "Problem identification and solving" and "Real-world cases." This indicates that students initially placed more emphasis on the process of PBL prior to undertaking the course, while certain associations became stronger after completing the course, aligning with the outcomes and experiences gained.

A similar analysis was also done with teachers/mentors when the keywords most commonly encountered in their responses were selected, and how their perception changed after PBL courses. Analysis of the appearance of selected keywords in the responses of teachers/mentors showed that the most common keyword appearance was: solving real-world challenges; applying methodology and involvement of different stakeholders; critical thinking skills; communication skills.

The survey showed that courses had a significant impact on the competences in both professional and personal fields. It can be seen that teachers/mentors are able to apply PBL methodology, involve different stakeholders, etc. It shows that after PBL courses teachers and mentors gained the ability to apply new teaching methodologies. The results of both students' and teachers'/mentors' analysis showed that most of the expectations raised before the PBL courses were achieved.

4 SUMMARY AND ACKNOWLEDGMENTS

Higher education institutions expect new pedagogical approaches and a shift towards active learning to produce industry-ready graduates with advanced problem-solving, communication, and multidisciplinary skills. Students associate PBL courses with improved teamwork, technical, design, communication, and presentation skills. Meanwhile, teachers/mentors emphasize the importance of involving stakeholders, promoting active engagement, and developing real-world problem-solving abilities through appropriate methodologies.

Moreover, the success of PBL integration initiatives relies heavily on continuous teacher support, motivation and networking with other universities in the region. The PBL South Asia project addresses this by creating a PBL network and online course for PBL applications in solving sustainability challenges, which serve as resources for teachers and students alike.

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REFERENCES

1. UNESCO. 2017. "Education for sustainable development: learning objectives". Accessed May 2, 2023. https://unesdoc.unesco.org/ark:/48223/pf0000247444_eng
2. Acharya, S., Bhatt, A. N., Chakrabarti, A., Delhi, V. S. K., Diehl, J. C., van Andel, E., Jurelionis, A., Stasiuliene, L., De Jussilainen Costa, L., and Subra, R. 2021. "Problem-based Learning (PBL) in undergraduate education : Design Thinking to Re-design Courses." In *Proceedings of International Conference: Research into Design.* Singapore: Springer.
3. Acharya, S., Bhatt, A.N., Chakrabarti, A., Delhi, V.S.K., Diehl, J.C., Mota, N.J., Jurelionis, A., and Subra, R. 2021. "Design Thinking as a strategy to inculcate Problem-based Learning (PBL) in undergraduate education across South Asian Universities." In *Proceedings of International Conference: Research into Design.* Singapore: Springer.
4. Duch, J. Barbara, Groh, E. Susan, and Allen, E. Deborah. 2001. *The power of problem-based learning: a practical "how to" for teaching undergraduate courses in any discipline.* 2001. Sterling, Virginia: Stylus Publishing, LLC.
5. Hmelo-Silver, C. E. 2004. "Problem-based learning: What and how do students learn?" *Educational psychology review*, 16, No. 3: 235-266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3.
6. Kolmos, Anette, and Erik de Graaff. 2014. "Problem-Based and Project-Based Learning in Engineering Education: Merging Models." Chapter. In *Cambridge Handbook of Engineering Education Research*, edited by Aditya Johri and Barbara M. Olds, 141–161. Cambridge: Cambridge University

Press. doi:10.1017/CBO9781139013451.012.

7. McCallum, E., McCallum, L., Weicht, R. and Kluzer, S. 2020. *The European Entrepreneurship Competence Framework in action in the labour market: a selection of case studies (EntreComp ant Work).* Publications Office of the European Union. DOI: 10.2760/673856.
8. PBL South Asia project. Available at: https://aaltoglobalimpact.org/pbl-south-asia/ .
9. Rajabifard, Abbas, Kahalimoghadam, Masoud, Lumantarna, Elisa, Herath, Nilupa, Hui, F. K. Peng, and Assarkhaniki, Zahra. 2021. „Applying SDGs as a systematic approach for incorporating sustainability in higher education", *International Journal of Sustainability in Higher Education*, 22(6): 1266-1284. https://doi.org/10.1108/IJSHE-10-2020-0418.
10. Savery, J. R.. 2015. *Essential Readings in Problem-Based Learning: Exploring and Extending the Legacy of Howard S. Barrows*. Purdue University Press. https://doi.org/10.2307/j.ctt6wq6fh.
11. Thomas, Ian. 2009. "Critical Thinking, Transformative Learning, Sustainable Education, and Problem-Based Learning in Universities", *Journal of Transformative Education*, 7(3): 245-264. https://doi.org/10.1177/15413446103857 .
12. Torp, L., and Sage, S. 2002. *Problems as Possibilities: Problem-Based Learning for K-16 Education.* Association for Supervision and Curriculum Development, p. 127.