PBL Meets AI: Innovating Assessment in Higher Education

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Keywords: Artificial Intelligence, Chatbot, Problem-Based Learning, Project-Based Learning, Learning Assessment.

Abstract: Problem-based and project-based learning (PBL) is a creative, inquiry-based process, enriched by teamwork, implemented through a longer timespan, with considerable student workload. As the process is normally conducted with a high level of student autonomy, there is often no way of monitoring what resources students rely on. In this context, the rapid availability of generative AI can support not only innovation, but also unfair practices. In this article, we will present case study research on the use of AI in PBL summative assessment in higher education, based on six courses. We analyzed and compared six courses of different levels of study (undergraduate, graduate, postgraduate), in different areas/subjects (mathematics, IT, project management, education). In some courses, it was obligatory to use AI, while in others it was either optional or not foreseen. We analyzed assessment results, student surveys and teacher testimonials, using mixed-method research. Based on the research cases, we identified three possible models of integrating AI in PBL and provided recommendations.

1 INTRODUCTION

The emergence of generative AI (GenAI), and particularly the release of OpenAI's ChatGPT chatbot in November 2022, has undoubtedly had a transformative impact on numerous aspects of the society. It has transformed the way we interact with technology, work, look for information, and the way we learn. As such, it has a potential to profoundly transform the way we teach as well.

In educational research, as well as in practice, both opportunities and challenges of such a powerful tool have already been recognized. On the one hand, GenAI has been found useful in terms of enabling easier access to knowledge, facilitating personalized learning and providing assistance in writing, research and analysis. On the other hand, it has also been linked with concerns related primarily to ethics, including the accuracy, quality and unbiasedness of educational content, as well as, notably, plagiarism. (Chan & Hu, 2023; Ray, 2023) On the latter, Noam Chomsky expressed the view that the use of GenAI chatbots is "basically high-tech plagiarism" and "a way of avoiding learning" (Marshall, 2023).

So, understandably, the rise of GenAI is making educators question their assessment practices. Can we prevent the misuse of GenAI? How can we maintain the fairness of the assessment process? But regardless of the concerns, it seems that the use of GenAI chatbots in education, however controversial, cannot be banned. This might be especially so in cases of learning approaches in which students have more independence and autonomy in their work, like problem-based and project-based learning (Spikol et al., 2018). So, instead of trying to prevent students to (mis)use new technology, we should embrace it (Rudolph et al., 2023). Therefore, the right questions to ask might be: How can we use GenAI to support, rather than undermine learning and assessment? Instead of seeing it as a disadvantage, how can we use it to our advantage?

In the light of these questions, we conducted case study research including six university courses, in which GenAI was used - either per teacher's instructions or autonomously - by students in the process of problem-based and project-based learning (PBL), as part of summative assessment.

While a number of studies have been conducted at the intersection of PBL and AI, there seems to be more focus on teaching and learning *about* AI than teaching and learning *with* AI. The aim of this study is to contribute to the developing body of knowledge on teaching and learning *with* AI, from the specific angle of problem-based and project-based learning, as approaches that offer, at the same time, more room for creativity and less room for teachers' control.

Divjak, B., Svetec, B. and Aničić, K. P.
PBL Meets AI: Innovating Assessment in Higher Education.
DOI: 10.5220/0013331700003932
Paper published under CC license (CC BY-NC-ND 4.0)
In *Proceedings of the 17th International Conference on Computer Supported Education (CSEDU 2025) - Volume 2*, pages 120-130
ISBN: 978-989-758-746-7; ISSN: 2184-5026
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2 THEORETICAL BACKGROUND

2.1 Problem-Based and Project-Based Learning

Problem-based learning (PrBL) and project-based learning (PjBL) are student-centered, creative, inquiry-based processes, rooted in constructivist learning theory (Dole et al., 2015). They both include learning activities towards a shared goal usually done by students in collaboration, with a high level of independence and autonomy (Brassler & Dettmers, 2017; Savery, 2006). As such, they are implemented through a longer time period, requiring substantial student workload. Despite many similarities, there are also specificities distinguishing between the two approaches (Dole et al., 2015).

Problem-based learning (PrBL) starts with a problem students are to learn about or solve (Dole et al., 2015). To solve the said problem, PrBL gives students an opportunity to investigate, apply their knowledge and skills, and combine theory with practice (Savery, 2006), and develop critical thinking (Kek & Huijser, 2011; Thorndahl & Stentoft, 2020). Problems are ill-structured, and often interdisciplinary, reflecting real-life complexity, and present the "driving force" of the learning process (Dole et al., 2015; Savery, 2006). These realistic and complex problems are usually solved in collaborative groups (Allen et al., 2011). An important element is guidance: the learning process is guided by a tutor, as a facilitator of learning (Allen et al., 2011; Savery, 2006). The tutor's role encompasses choosing a problem, providing assistance and motivation to students, articulating the problem-solving process (Doumanis et al., 2021) and, in the end, carrying out a detailed debriefing (Savery, 2006). While students do present the conclusion they reached, the process does not necessarily result in a concrete product (Dole et al., 2015). PrBL supports students in both acquiring and applying knowledge and skills (Dochy et al., 2003), fostering deep understanding and particularly the development of process-related skills like research, teamwork, negotiation, writing, verbal communication (Allen et al., 2011).

However, PrBL is not without challenges for teachers, calling for institutional support and training (Savery, 2006). The challenges often relate to large classes, students resisting group work, but also assessment metacognition and procedural knowledge. Finally, the essential shift from teachers providing knowledge to tutors facilitating learning (Savery, 2006).

Project-based learning (PjBL), similarly, also uses real-world problems, and fosters collaboration, critical thinking and interdisciplinary knowledge. But contrary to PrBL, it starts with the vision of an artifact, which presents the "driving force", and is based on problems that reflect real-world. The production process leads to the acquisition of knowledge and skills, needed for successful finalization of the artifact (Dole et al., 2015). While PrBL focuses on knowledge application, PjBL emphasizes knowledge construction.

Contrary to PrBL, in PjBL, students are provided with clear instructions and guidelines for the final artifact, and receive continuous feedback and guidance from their teachers, who act as instructors or coaches. Teachers are more flexible in terms of giving direct instruction and support to students, but still need to ensure balance enabling students to acquire the intended outcomes while fostering self-directed learning (Savery, 2006). Students' problem-solving in PjBL takes more time. Being aware of the differences between the two approaches, for the purpose of this paper, we use a single abbreviation, PBL, as the aspects important for this study are relevant for both approaches.

2.2 AI and Chatbots in Education

Previous research has shown that chatbots can be useful in supporting students to learn basic content in an interactive, responsive and confidential way (Chen et al., 2023). Some of the identified benefits of using chatbots include integration of content, quick access, motivation, engagement, access for multiple users, immediate assistance and support, as well as encouraging personalized learning (Clark, 2023; Okonkwo & Ade-Ibijola, 2021). Nevertheless, there are also challenges, regarding ethics, assessment, user attitude, supervision and maintenance, as well as the constraints of natural language processing and the limited possibility of thorough customized conversations (Clark, 2023).

Regardless of the limitations, chatbots have been used in education in various ways (Clark, 2023), for example, as interactive knowledge bases (Chang et al., 2022), virtual students (Lee & Yeo, 2022), learning partners (Fryer et al., 2019), or help in exam preparation (Korsakova et al., 2022).

Since its release, much of the focus in this area has been on Open AI's ChatGPT, generating "more natural-sounding and context-specific responses" (Dai et al., 2023). It has been noted that GenAI

chatbots like ChatGPT can be used, on the one hand, as learning partners or tutors, and support self-regulated learning (Dwivedi et al., 2023), but on the other hand, as a means to pass exams without or with minimal learning. Therefore, educators have been emphasized as those responsible to support students' development of critical thinking, while being receptive to experimentation and navigating transformation (Dwivedi et al., 2023). Furthermore, potential applications of ChatGPT have been identified in terms creating personalized learning materials, lesson plans, engaging educational content, and adaptive learning environments, providing immediate and constructive feedback to students, and helping teachers with grading (Ray, 2023).

In the light of the said developments, the use of ChatGPT in education has been in the focus of recent research endeavors, including its use in assessment. Importantly, it has been found (Clark, 2023) that ChatGPT is not as successful in problem-solving and open-ended questions as in answering closed-ended questions, and it could be useful in assignments which include students analyzing the chatbot's output to improve it.

Meaningful integration of AI in education has been perceived as a lengthy process (Rudolph et al., 2023), especially if based on a top-down policy development approach. Therefore, our aim is to use a bottom-up approach to identify best practices and speed up the process and enhance the quality of integration of AI in education.

3 METHODOLOGY

Our research was focused on the following research questions:
RQ1. How do students use AI chatbots in PBL?
RQ2. What are the benefits and risks of possible teachers' approaches to integrating AI in PBL?
RQ3. What are generic models of using generative AI by students in PBL related to study levels, experience with AI and type of assessment?

To answer these questions, we used mixed-method research, in particular, multi-case study research methodology (Yin, 2017). The study was done in line with an action research approach, directed towards introducing changes in practice (Clarke, 2023), with course teachers studying their own classrooms (Mertler, 2020). In this sense, it involved course teachers as researchers, but also research participants, with a focus on reflective practice (Cohen et al., 2011). With action research being a less intrusive approach to research, the study was conducted based on several types of data and analyses, depending on availability.

3.1 Study Setting

The study was conducted in academic years 2022/2023 and 2023/2024 at a higher education institution (HEI) offering undergraduate, graduate and postgraduate study programs in IT and related fields like e-learning. Specifically, the study encompassed six courses:

- Undergraduate level: Mathematics 2 (MAT2), Introduction to IT Projects (IITP), Informatics Services Management (ISM)
- Graduate level: Project Cycle Management (PCM), Project Cycle Management in IT (PCM IT)
- Postgraduate level: E-Learning Strategy and Management (ELSM)

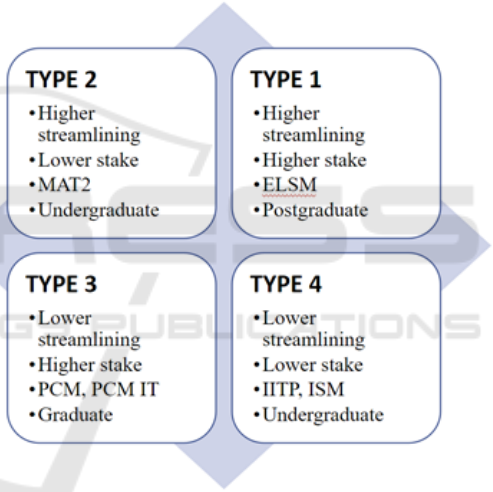

Figure 1: Research cases (courses) in a multi-case study matrix.

We described four types of research cases by placing the chosen courses (Table 1) in a matrix (Figure 1) (Yin, 2017) based on two categories: (1) the level of teachers' streamlining of students' use of AI in PBL and (2) the influence of the PBL task on the final grade. Additionally, we chose research cases of different levels of study: undergraduate (bachelor), graduate (master) and postgraduate.

TYPE 1. E-Learning Strategy and Management (ELSM). This is a first-year postgraduate level course (study program: E-learning in Education and Business), with a student workload of 5 ECTS credits (around 150 hours). The assessment program includes regular quizzes and discussions (formative assessment) and assignments

Table 1: Research cases descriptions.

Course & subject area	Type of activity	Phase of PBL	Individual/ team	Use of AI
E-Learning Strategy and Management Education	Preparing a strategic plan for e-learning	Initiating and planning	Individual	Students **were instructed** to use AI
Mathematics 2 Mathematics	Solving mathematical problems	Problem-solving	Individual	Students **were instructed** how to use a chatbot
Project Cycle Management Project Management	Preparing a project proposal for EU funding	Artifact production	Team	Students **were not recommended** to use AI
Introduction to IT Projects Project Management	Preparing an initial IT project description	Initiating and planning	Team	Students **were not recommended** to use AI
Informatics Services Management IT	Preparing a needs analysis for IT services	Initiating and planning	Team	Students **were allowed (but not instructed) to use AI**
Project Cycle Management in IT Project Management, IT	Preparing a project proposal for EU funding	Artifact production	Team	Students **were not recommended** to use AI

done by the students either individually or in teams (summative assessment). One of these assignments refers to an essay on a chosen topic related to strategic decision-making based on relevant data sources, and another is an essay on scenarios of the future of education. Each of the assignments contributes 10% to the total grade. In the academic year 2023/2024, the students were instructed to use a GenAI chatbot like ChatGPT in the preparation of the two essays and include a critical reflection on the results in their essays. Both assignments are assessed based on criteria and a rubric that includes the assessment of the use of AI. The students were asked to fill in a short questionnaire about their experience with the use of an AI chatbot.

TYPE 2. Mathematics 2 (MAT 2). This is a first-year undergraduate level course (study program: Informatics), with student workload amounting to 6 ECTS credits (about 180 hours). The assessment program includes quizzes and homework assignments (formative assessment), three periodical exams and a problem-solving essay (summative assessment). The essay contributes 10% to the total grade. In the academic years 2022/2023 and 2023/2024 the essay exercise has been upgraded to include GenAI to assist students in problem-solving, and students' critical reflection on GenAI as a partner in PBL. Students were given individualized problem-solving tasks with instructions on how to use GenAI in PBL. They had to report on the results of their work with GenAI, and then further research a given topic to solve a mathematical problem; they were asked to analyze the solutions and provide a critical evaluation of their work with GenAI. Students also provided feedback on the problem-solving task via a questionnaire.

TYPE 3. Project Cycle Management (PCM). This is a second-year graduate level course (study program: Economics), with a workload of 4 ECTS credits (about 120 hours). The assessment program includes homework assignments (formative assessment), two periodical exams and preparation of a project application using PBL (summative assessment). PBL contributes 40% to the final grade. The project application is prepared in a team, and in line with a relevant financing program. In the academic year 2023/2024, students were given a simplified Erasmus+ project application template, and worked on its parts in classes, where they received formative feedback, but had to complete the project application autonomously as a team. In doing so, they were not advised to use the support of GenAI. Project applications were assessed based on a rubric. The students were asked to fill in a short

Table 2. Data collection and analysis.

Course	Source of information	Analysis	Sample
E-Learning Strategy and Management	Reported by students in assignments; teachers' insights from students' assignments; a follow-up questionnaire	Quantitative and qualitative	32 students 3 teachers
Mathematics 2	Reported by students in the essay and the follow-up questionnaire	Quantitative and qualitative	229 students 6 teachers
Project Cycle Management	Teachers' insights from students' assignments; a follow-up questionnaire	Quantitative and qualitative	21 students 3 teachers
Introduction to IT Projects	Teachers' insights from students' assignments; discussion in classes	Qualitative	91 students 3 teachers
Informatics Services Management	Teachers' insights from students' assignments; discussion in classes	Qualitative	210 students 6 teachers
Project Cycle Management in IT	Teachers' insights from students' assignments; a follow-up questionnaire	Qualitative	9 students 3 teachers

questionnaire which questions about their (possible) use of AI in the preparation of the project application.

TYPE 3. Project Cycle Management in IT (PCM IT). This is a first-year graduate level course (study program: Informatics), with a workload of 4 ECTS credits (about 120 hours). The assessment program includes quizzes and homework (formative assessment), two periodical exams and two PBL-type project assignments (summative assessment). PBL is done in teams and contributes 60% to the final grade. In the first project assignment, students plan an IT project using the standard IT project management methods. In the second project assignment, students prepare a project application in line with a relevant financing program. In the academic year 2023/2024, students worked on a simplified EU-financed, IT-related project application template, with parts of the application discussed in classes, where students received formative feedback. The project application was finalized autonomously by each team, whereas the teams were not advised to use the support of GenAI. Project applications were assessed based on a rubric. The students filled in a short questionnaire including questions about the (possible) use of AI while working on the project application.

TYPE 4. Introduction to IT Projects. This is a second-year undergraduate level course (study program: Applied IT), with a workload of 3 ECTS credits (about 90 hours). The assessment program includes weekly assignments during seminars (formative assessment), two periodical exams and a PBL-type of an IT project (summative assessment). PBL contributes 40% to the final grade. In academic year 2023/2024 students were given a task to make a proposal for an IT project with the description of its main elements. Student proposals were submitted in the LMS and discussed with teachers and peers in classes. Students were not recommended to use the support of GenAI in this task.

TYPE 4. Informatics Services Management (ISM). This is a second-year undergraduate level course (study program: Informatics), with a student workload of 4 ECTS credits (about 120 hours). The assessment program includes assignments during laboratory exercises (formative assessment), two periodical exams and a prototype developed using the PBL approach (summative assessment). PBL contributes 50% to the final grade. In the academic year 2023/2024, each student group was given a project task by the teacher. Students worked on assignments every week in laboratory exercises and continued at home. Students were allowed to use AI during laboratory exercises and discussed the obtained solutions with the teacher, as a part of formative assessment.

3.2 Data Collection and Analysis

The data were collected in academic years 2022/2023 and 2023/2024. Depending on the course, the data included data collected directly from students (assessment grades, reporting in assignments, and questions about the use of AI integrated in student questionnaires at the end of the course) and teacher testimonials (based on insights from students' assignments and discussions in class). As, in line with

the action research approach, teachers/researchers studied their own classrooms and provided testimonials immediately after teaching and learning activities were done, convenience sampling was done based on the availability of the respective courses' data (Cohen et al., 2011). However, importantly, the sampling of courses was targeted in a way to include several levels of study and several scientific disciplines. More details on the data collection and analysis are presented in Table 2.

4 RESULTS

4.1 e-Learning Strategy and Management

Within the two assignments of this course, students were instructed to use AI and then report and critically reflect on their work with AI. It should be noted that the students of this course are adult students, primarily in-service teachers.

The students were interested in the assignments, which is reflected in the fact that 30 out of 32 students filled-in the questionnaire to share their experience, and the fact that 67% reported that using AI in the assignments was interesting to them. A vast majority of students were in-service K-12 teachers, whose interest in the use of AI was additionally triggered by these assignments, as they motivated them to use AI in their own teaching practices. All the students replied that, after the assignments, they were going to use AI in a supervised way in their classrooms even if they had not done that before. While 37% already had used AI before, 63% had not. A vast majority of the students (67%) reported that they would have used AI even if it were not instructed by the course teachers, while only one third of the students would not mention that in the references.

When asked about the positive sides of using AI chatbots, a majority of students found them useful in terms of providing the overall structure of the topic, new hints and ideas, and direction for further research. A third of the students pointed out that AI chatbots were useful in providing fast access to basic information. Several students also identified pros in terms of text formulation, creation of tables, graphs and graphic representations, and summarizing sources. When it comes to the negative sides, a third of the students thought that AI chatbots were not reliable and trustworthy, providing incorrect and invented information. In this sense, some stressed the need for a critical approach and checking the accuracy of the answers, which means extra work for the students.

While assessing student's assignments, the teachers observed that the students did use AI and refer to it in their assignments, but the reported output of AI was often generic and not substantive. This may be related to AI's non-specific responses, but also to the students' not-so-well-targeted prompts. Moreover, the students often provided no critical reflection on the AI's responses, or their reflection was rather superficial, lacking critical analysis and fact-checking. Finally, the teachers reported that giving constructive feedback, which would refer both to the content and the critical use of AI, was time-consuming.

4.2 Mathematics 2

In the PBL within this course, the use of an AI chatbot was also highly structured, with students receiving clear instructions on how to use and report on their work with AI. Student assessment results achieved without and with chatbots (in two consecutive years, 2021/2022 and 2022/2023) were comparable, though the results were slightly better without chatbots. Furthermore, students who performed better in the entire course were also more successful in PBL. Importantly, a great majority of students reported they already had experience in the use of chatbots for learning.

Students' responses to the questionnaire indicated that they found AI chatbots to be useful in finding and verifying information, but were not worried about its accuracy, particularly when it comes to calculations in mathematics, and were not very satisfied with AI's recommending capabilities in terms of literature, or effectiveness in problem-solving. The comprehensive results related to the use of AI in PBL within this course in academic year 2022/2023 have been described in the article entitled *Generative AI in mathematics education: analysing student performance and perceptions over three academic years* (Divjak et al., 2025).

Additionally, according to course teachers' testimonials, the PBL exercise supported by AI was successful, as the students learned about the benefits and downsides of the use of AI. Teachers are less worried about AI's capability of correct calculation, and more about misinterpretation of mathematical concepts. Understanding mathematical concepts is essential for developing mathematical reasoning. Finally, teachers reported that designing meaningful assignments, in a way that enables a critical approach to the use of AI, for a large group of students, was highly demanding.

4.3 Project Cycle Management and Project Cycle Management in IT

In the PBL tasks within these two courses, the use of AI was not recommended. While assessing students' projects, the course teachers gave feedback to some student teams mentioning that the teachers noticed the use of AI in descriptive parts. The teachers recognized the use of AI chatbots primarily based on the way the text was formed: general in terms of content and complex in terms of expression. At the same time, the students did not add AI chatbots in the lists of references.

In the questionnaire, almost all the students (21/22) reported using the support of AI tools at least to some extent, but none reported using it to a great extent. More than a half of the students (55%) reported using it moderately or quite a lot, while less than a half (41%) reported using it a little. Students reported that they predominantly used AI for work-intensive tasks like preparing the project budget, risk analysis, project management description and horizontal topics (e.g., green practices, inclusiveness).

4.4 Introduction to IT Projects

In PBL, the use of AI was not recommended. When analyzing the students' assignments, the course teacher noticed the use of AI in the following elements: the used vocabulary is not common for students, as it includes complex and professional terms; students were not able to elaborate the meaning of certain text; the structure of the elaboration of the project idea (i.e. phases of IT project development) was repeated in several teams in an almost identical way, although the students did not receive instructions for a specific structure; moreover, students were not able to elaborate if they have learned such structure in some other courses; in expressing the IT project budget, some teams made obvious mistakes as a result of non-critical text-copying (e.g. used dollars instead of euros). During the discussion with the teacher and peers, the students admitted that they used an AI chatbot to prepare project proposals for the mentioned elements observed by the teacher but were not aware they should reflect on that.

4.5 Informatics Services Management

In PBL, students were allowed, but not instructed to use AI. Although teachers allowed students to use AI chatbots during exercises, students rarely used them. However, when discussing homework assignments, teachers noted (and students confirmed) that they used AI. Considering that these are creative tasks that require thinking about the given problem and the end users of the solution, the teachers noticed that in certain segments the students' solutions were very generic and insufficiently concrete. For example, students asked AI to propose steps in a customer journey map and the biography for persona, but they received very generic solutions as they did not include more detailed information about their concrete project task to the query posed to AI. Teachers noted that the solutions obtained by the AI should have been further refined by the students in most cases.

5 DISCUSSION

In PBL students develop critical thinking and use different resources, simulating the real world (Savery, 2006), and AI can be used to support this. The six presented research cases describe situations of using generative AI for PBL, which generally gives students a certain rate of autonomy and flexibility in terms of organizing their own learning and problem-solving. But this "hands-on and open-ended nature" of PBL also means less control for teachers and more complex tracking of the integrity of students' work. (Spikol et al., 2018)

It should be noted that PBL cannot be integrated in the same way in every subject, as well as that the integration of AI in teaching, learning and assignments depends on the specificities of the course content and learning outcomes. It was our aim to illustrate different approaches and practices and generalize some aspects in order to provide a framework which can accommodate different courses.

5.1 How Students Use AI in PBL

Considering the presented cases, we identified several possible ways in which students can use AI in PBL tasks, as presented in Figure 2. With the rapid rise of GenAI, especially since November 2022 and the launch of ChatGPT 3, students started increasingly using GenAI chatbots in their assignments, and usually did not report on that *(Sneaking)*. Some teachers recognized this and started openly discussing the use of GenAI in assignment preparation when they noticed ideas and patterns possibly produced by GenAI. Teachers tried to integrate GenAI in the initial phases of PBL, low-stake in terms of assessment, like

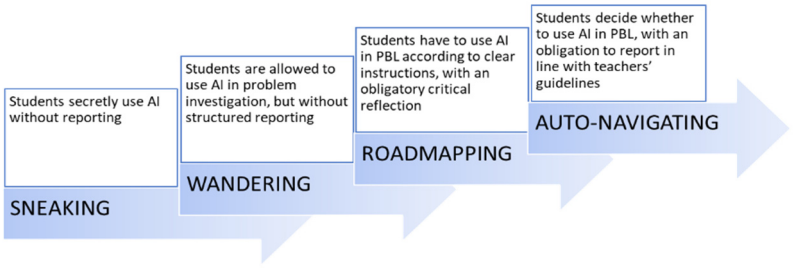

Figure 2: How students use AI in PBL.

in problem investigation *(Wandering)*. In order to streamline the process and facilitate the recognition of benefits and challenges of the use of AI by students, teachers integrated AI as an obligatory tool in PBL assignments, but with clear instructions for students on how to use AI and critically reflect on that. This contributed to the development of AI literacy of both students and teachers *(Roadmapping)*, in terms of not only using AI applications, but also understanding the underlying concepts and related ethical concerns, as a prerequisite for responsible use of AI (Ng et al., 2021). Finally, the goal is to support informed use of AI by students, in which case AI can be an optional tool, but students have the responsibility to report on the use of AI and use it critically, applying their AI literacy skills and being mindful of the considerations of AI ethics (European Commission, 2019) *(Auto-navigating)*.

5.2 Benefits and Risks of Teachers' Approaches to Using AI in PBL

Teachers can take different approaches to integrating (or not) AI into PBL:

A teacher can simply forbid or ignore the use of AI. Our results show that students use AI regardless of their teachers' explicit permission (e.g., in the PCM courses). Students can benefit from additional and instantly available sources and support, but this can also lead to misinformation and misguidance from AI. On the one hand, an experienced teacher can detect the use of AI in students' assignments even though it is not reported. On the other hand, there is a risk that an inexperienced teacher will not detect the use of AI, and award a student with credits that are not fairly deserved. In this case, students who secretly use AI may get better grades, without acquiring learning outcomes. This "ostrich" approach can be harmful for students' learning and the development of academic integrity. Considering the risks, this "policing" approach has not been recommended (Rudolph et al., 2023) and should better be avoided by teachers when using PBL.

A teacher can make the use of AI obligatory. Our results show that students can benefit from structured use of AI, which is interesting and challenging, since it requires a critical approach to AI outputs (for example, Mathematics 2 and E-Learning Strategy and Management). Among the benefits, AI can provide students with hints for orientation within a new topic and direction for further research. Moreover, this approach contributes to the development of students' and teachers' AI literacy, students' critical thinking, and recognizing the principles of academic integrity. However, there is a risk that some students would not recognize misinformation provided by AI. Moreover, this "shepherd dog" approach limits students' flexibility and undermines self-regulation. For teachers, it may be time consuming to give constructive feedback on both the content of the PBL assignment and students' critical use of AI. Moreover, not any topic is appropriate for work with AI in a way that enables substantial critical analysis by students, which calls for a substantial level of teachers' AI and assessment literacy. Finally, this approach is neither appropriate for any PBL assignment, nor is it beneficial for all students for a longer period of time.

A teacher can make the use of AI optional. This "owl" approach is suitable for AI literate students and teachers, who accept AI as imperfect, but immediate support, and are skillful in using AI in line with general academic principles. In terms of benefits, this approach supports self-regulated learning and students' autonomy. On the other hand, teachers have to be able to either trust that their students use AI responsibly or critically reflect on their students' assignments in terms of detecting potential unfair practices. This approach should be risky if not preceded by adequate preparation of students or an approach like the previous one. Furthermore, it calls for careful assessment planning and possible redesign of assessment criteria, to take into account that some students do use AI while others do not, and ensure fair assessment.

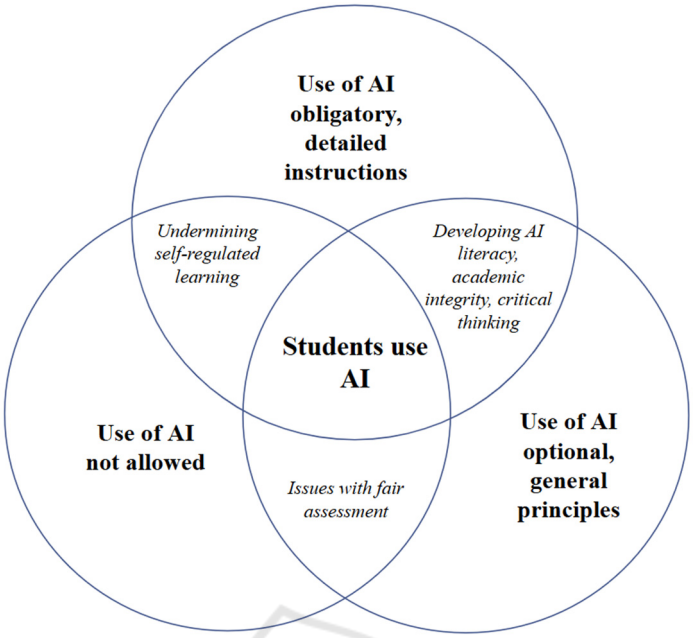

Figure 3: Major benefits and risks of teachers' approaches

Figure 3 presents the major benefits/risks at the intersections of these approaches.

5.3 Models of Integrating AI in PBL

The assessment tasks described in the research case studies differ in at least three aspects. First, the extent to which the teacher streamlines the process of integrating AI in PBL. Second, the influence of the PBL task on the final grade. Third, the level of HE. The benefits and risks of different teachers' and students' approaches were covered in previous sections. Based on the presented research cases and analyses, we further describe three models of using AI in PBL, applicable in different contexts.

Model 1 (FIRM): The teacher requires the use of AI in PBL, gives instructions on how to use it and how to reflect on the results, since GenAI is not very reliable in problem-solving (Clark, 2023). The aim is to provide students with an experience in learning with AI and a critical understanding of its benefits and downsides. This is recommended in the case of high-stake (summative) assessment and on lower levels of HE, and when students are less familiar with academic integrity, including responsible use of AI.

For example, MAT2 and ELSM courses describe situations where students practice how to use AI, creating meaningful prompts and recognizing limitations. Results show that students are satisfied with this guided way of using AI and find it interesting. On the one hand, students practice critical thinking and AI literacy, and on the other hand, teachers know what they are assessing and can assess the critical analysis of answers.

This model is important for freshmen and those just being introduced to a subject, or when (institutional) practices in the use of AI are still being established: e.g., how it is used, referenced, what is author's contribution. Ideally, the goal is to progress towards the model in which the use of AI is optional, but with clear institutional guidelines.

Model 2 (RELAXED): The teacher allows the use of AI, but does not give instructions about reflection and reporting. This is suitable for initial phases of PBL, when results can still be discussed and AI outputs can later be adequately referenced. Moreover, this model can be used once students have already gone through the "firm" model 1 and have already acquired the critical AI literacy skills, including academic integrity. Otherwise, students can be confused about the use of AI.

For example, in ISM and IITP courses, students admitted that they had used AI at home, but in class (although they were allowed) they hesitated to use it. This might be because they had already accepted AI as a tool for cheating. In this model, transparency should be insisted on, and AI presented as a legitimate tool and their "teammate" (Fryer et al., 2019). Students still need to be provided with some guidance on the use of AI if they are not skilled in asking questions in problem-based tasks that require creative solutions.

This model is applicable primarily in formative assessment, when teachers still give feedback in the problem-solving process. This model gives teachers the possibility to calibrate the instrument for summative assessment. However, summative assessment requires a more structured approach.

Model 3 (FLEXIBLE): Teachers do not give instructions on the use of AI, but students use it anyway. As such situations cannot be controlled in PBL, it is better to think of ways of using AI in a structured way, to support students' problem-solving skills. However, this does not imply that the use of AI should be obligatory, but an option should be left to students to decide whether to use it, with a responsibility of reporting.

For example, looking at the PCM courses, the conclusion is that teachers cannot ban the use of AI as they do not control the PBL environment. Teachers can indirectly find out (or not) that students used AI, which may have an impact on fairness of assessment.

In order to successfully implement this "flexible" model, in which students have a choice to use or not use AI in PBL summative assessment, students and teachers have to be sufficiently mature and literate in terms of using AI. To achieve this, a prior implementation of the "firm" model 1 can be an asset. Alternatively, training and institutional guidelines for teachers and students provided by a HEI can be beneficial.

5.4 Limitations and Further Research

The main limitation of this study is that it includes a limited number of research cases, courses belonging to specific subject areas. Furthermore, the data collected in relation to the said research cases differs in volume, type and quality. Therefore, it would be valuable to conduct further research in other educational contexts, harmonize the data collection, and based on that, conduct more sophisticated statistical analyses.

6 CONCLUSION

We conducted case study research including six research cases - courses at all the three levels of higher education - to analyze approaches to the use of AI in project-based and problem-based learning (PBL). Based on the six cases, we identified three possible models of introducing AI in PBL. The three models differ in several aspects. The first one refers to whether the use of AI in PBL is obligatory, optional or not allowed. The second refers to whether learning with AI is done in line with detailed teachers' instructions or students use AI more flexibly, but (presumably) in line with general academic and ethical principles. The third difference refers to whether PBL-based assessment is high-stake or low-stake. The analysis showed that it is advisable to start with the introduction of AI in PBL as early during the studies as possible, and that students benefit from structured and comprehensive instructions. This also contributes to the trustworthiness of the use of AI in PBL, as well as to the AI literacy of students. This is especially relevant in cases of high-stake PBL assessment. In the second phase of integration of AI in PBL, the use of AI can be optional for students, but, if used, it should be reflected on and reported, to ensure ethics and academic integrity, as well as critical use of AI. We should be aware that the use of AI in PBL is not something that can or should be forbidden. On the one hand, this is due to less teacher control of students' learning processes. On the other hand, AI is here to stay, and we should learn how to meaningfully use it in problem-solving and creating creative project-based solutions.

ACKNOWLEDGEMENT

This work has been supported in part by the *Trustworthy Learning Analytics and Artificial Intelligence for Sound Learning Design* (TRUELA) project, financed by the Croatian Science Foundation (IP-2022-10-2854).

REFERENCES

Allen, D. E., Donham, R. S., & Bernhardt, S. A. (2011). Problem-based learning. *New Directions for Teaching and Learning*, *2011*(128), 21–29. https://doi.org/10.1002/tl.465

Brassler, M., & Dettmers, J. (2017). How to Enhance Interdisciplinary Competence—Interdisciplinary Problem-Based Learning versus Interdisciplinary Project-Based Learning. *Interdisciplinary Journal of Problem-Based Learning*, *11*(2). https://doi.org/10.7771/1541-5015.1686

Chan, C. K. Y., & Hu, W. (2023). Students' voices on generative AI: perceptions, benefits, and challenges in higher education. *International Journal of Educational Technology in Higher Education*, *20*(1), 43. https://doi.org/10.1186/s41239-023-00411-8

Chang, C.-Y., Kuo, S.-Y., & Hwang, G.-H. (2022). Chatbot-facilitated Nursing Education: Incorporating a Knowledge-Based Chatbot System into a Nursing Training Program. *Educational Technology & Society*, *25*(1), 15–27.

Chen, Y., Jensen, S., Albert, L. J., Gupta, S., & Lee, T. (2023). Artificial Intelligence (AI) Student Assistants in the Classroom: Designing Chatbots to Support Student Success. *Information Systems Frontiers*, *25*(1), 161–182. https://doi.org/10.1007/s10796-022-10291-4

Clark, T. M. (2023). Investigating the Use of an Artificial Intelligence Chatbot with General Chemistry Exam Questions. *Journal of Chemical Education*, *100*(5), 1905–1916. https://doi.org/10.1021/acs.jchemed.3c00027

Clarke, A. (2023). 'Teacher inquiry: by any other name', in Tierney, R. J., Rizvi, F., and Ercikan, K. (eds) *International Encyclopedia of Education (Fourth Edition)*. Elsevier, pp. 232–242.

Cohen, L., Manion, L. and Morisson K. (2011). Research Methods in Education, 7th Edition, Routledge, Taylor and Francis Group.

Dai, W., Lin, J., Jin, H., Li, T., Tsai, Y.-S., Gašević, D., & Chen, G. (2023). Can Large Language Models Provide Feedback to Students? A Case Study on ChatGPT. *2023 IEEE International Conference on Advanced Learning Technologies (ICALT)*, 323–325. https://doi.org/10.1109/ICALT58122.2023.00100

Divjak, B., Svetec, B., Horvat, D. (2025). Generative AI in Mathematics Education: Analysing Student Performance and Perceptions over Three Academic Years. *International Journal of Technology Enhanced Learning*. Accepted for publication.

Dochy, F., Segers, M., Van den Bossche, P., & Gijbels, D. (2003). Effects of problem-based learning: a meta-analysis. *Learning and Instruction*, *13*(5), 533–568. https://doi.org/10.1016/S0959-4752(02)00025-7

Dole, S., Bloom, L., & Kowalske, K. (2015). Transforming Pedagogy: Changing Perspectives from Teacher-Centered to Learner-Centered. *Interdisciplinary Journal of Problem-Based Learning*, *10*(1). https://doi.org/10.7771/1541-5015.1538

Doumanis, I., Sim, G., & Read, J. (2021). *Problem-Based Learning and AI, ALIEN Active Learning in Engineering Education*. http://projectalien.eu/wp-content/uploads/2021/03/D4.1-PBLand-AI-community-document.pdf

Dwivedi, Y. K., Kshetri, N., Hughes, L., Slade, E. L., Jeyaraj, A., Kar, A. K., Baabdullah, A. M., Koohang, A., Raghavan, V., Ahuja, M., Albanna, H., Albashrawi, M. A., Al-Busaidi, A. S., Balakrishnan, J., Barlette, Y., Basu, S., Bose, I., Brooks, L., Buhalis, D., … Wright, R. (2023). Opinion Paper: "So what if ChatGPT wrote it?" Multidisciplinary perspectives on opportunities, challenges and implications of generative conversational AI for research, practice and policy. *International Journal of Information Management*, *71*, 102642. https://doi.org/10.1016/j.ijinfomgt.2023.102642

European Commission. (2019). Ethics Guidelines for Trustworthy AI. https://digital-strategy.ec.europa.eu/en/library/ethics-guidelines-trustworthy-ai

Fryer, L. K., Nakao, K., & Thompson, A. (2019). Chatbot learning partners: Connecting learning experiences, interest and competence. *Computers in Human Behavior*, *93*, 279–289. https://doi.org/10.1016/j.chb.2018.12.023

Kek, M. Y. C. A., & Huijser, H. (2011). The power of problem-based learning in developing critical thinking skills: preparing students for tomorrow's digital futures in today's classrooms. *Higher Education Research & Development*, *30*(3), 329–341. https://doi.org/10.1080/07294360.2010.501074

Korsakova, E., Sokolovskaya, O., Minakova, D., Gavronskaya, Y., Maksimenko, N., & Kurushkin, M. (2022). Chemist Bot as a Helpful Personal Online Training Tool for the Final Chemistry Examination. *Journal of Chemical Education*, *99*(2), 1110–1117. https://doi.org/10.1021/acs.jchemed.1c00789

Lee, D., & Yeo, S. (2022). Developing an AI-based chatbot for practicing responsive teaching in mathematics. *Computers & Education*, *191*, 104646. https://doi.org/10.1016/j.compedu.2022.104646

Marshall, C. (2023). Noam Chomsky on ChatGPT: It's "Basically High-Tech Plagiarism" and "a Way of Avoiding Learning." *Open Culture*. https://www.openculture.com/2023/02/noam-chomsky-on-chatgpt.html

Mertler, C. A. (2020). Action research: Improving schools and empowering educators (6th ed.). SAGE.

Ng, D. T. K., Leung, J. K. L., Chu, S. K. W., Qiao, M. S. (2021). Conceptualizing AI literacy: An exploratory review, *Computers and Education: Artificial Intelligence*, 2. https://doi.org/10.1016/j.caeai.2021.100041

Okonkwo, C. W., & Ade-Ibijola, A. (2021). Chatbots applications in education: A systematic review. *Computers and Education: Artificial Intelligence*, *2*, 100033. https://doi.org/10.1016/j.caeai.2021.100033

Ray, P. P. (2023). ChatGPT: A comprehensive review on background, applications, key challenges, bias, ethics, limitations and future scope. *Internet of Things and Cyber-Physical Systems*, *3*, 121–154. https://doi.org/10.1016/j.iotcps.2023.04.003

Rudolph, J., Tan, S., & Tan, S. (2023). ChatGPT: Bullshit spewer or the end of traditional assessments in higher education? *Journal of Applied Learning & Teaching*, *6*(1). https://doi.org/10.37074/jalt.2023.6.1.9

Savery, J. R. (2006). Overview of Problem-based Learning: Definitions and Distinctions. *Interdisciplinary Journal of Problem-Based Learning*, *1*(1). https://doi.org/10.7771/1541-5015.1002

Spikol, D., Ruffaldi, E., Dabisias, G., & Cukurova, M. (2018). Supervised machine learning in multimodal learning analytics for estimating success in project-based learning. *Journal of Computer Assisted Learning*, *34*(4), 366–377. https://doi.org/10.1111/jcal.12263

Thorndahl, K. L., & Stentoft, D. (2020). Thinking Critically About Critical Thinking and Problem-Based Learning in Higher Education: A Scoping Review. *Interdisciplinary Journal of Problem-Based Learning*, *14*(1). https://doi.org/10.14434/ijpbl.v14i1.28773

Yin, R. K. (2017). *Case Study Research and Applications: Design and Methods, 6th Ed.* Sage Publications Inc.