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The Role of Artificial Intelligence in Project-Based Learning: Teacher Perceptions and Pedagogical Implications

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Abstract: This study is based on the development of a design focused on underlining what artificial intelligence can achieve to bring value to learning quality especially when implementing active methodologies, such as project-based learning (PBL). This study analyzed the perceptions of AI-integrated PBL versus non-AI-integrated PBL among teachers in primary, secondary, and higher education. Conducted with a sample of teachers (n = 300), this study investigated perceived effectiveness, the AI-powered personalization of learning, and motivation. A Student's *t*-test, as well as normality, homogeneity of variance, and Cohen's d tests, revealed that AI-enhanced PBL is rated significantly higher than regular PBL without AI, with a Cohen's d effect size of 1.30, signifying a large impact. These findings underpin the development of an optimized AI-driven PBL model, particularly within both the prototype production and evaluation phases, providing greater autonomy, responsive feedback, and adaptive personalization, all towards advancing a more effective AI-supported pedagogical model of teaching.

Keywords: artificial intelligence; project-based learning; teacher perception; educational technology; active pedagogies

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1. Introduction

Project-based learning (PBL) is a widely used methodology for developing key competencies in students, such as critical thinking, collaboration, and autonomy, by engaging them in real-world problem-solving projects (Almulla, 2020; Barros et al., 2023). Within this approach, artificial intelligence (AI) emerges as a transformative tool, offering personalization and adaptive feedback that improves the educational experience and fosters student motivation (Holmes et al., 2019; Kanders & Müller, 2024). This study builds on a bibliographic review of existing research on AI in project-based learning (PBL). (Roll & Wylie, 2016) emphasize the role of adaptive AI systems in promoting student autonomy, while Zawacki-Richter et al. (2019) highlight the capacity of AI to personalize the learning process. Su (2022) and Mutawa and Sruthi (2023) further investigate the possibilities of using AI to reduce academic anxiety through real-time feedback.

PBL prompts the personalization of learning owing to AI, which can be exploited for real-time reflection on learning outcomes, and students can customize content and difficulty based on performance. This adjustment leads to the development of a reduction in academic anxiety and performance enhancement (Mutawa & Sruthi, 2023; Inoferio et al., 2024; Beketov, 2024). AI serves as an important means of obtaining continuous feedback and self-assessment throughout the critical stages of project production and review (Tariq, 2025; Dahmen et al., 2020; Zha et al., 2024), offering specific and personalized recommendations

for enhancing the quality of students' prototypes and development. Additionally, characterizing the accurate tracking of progress via deep learning algorithms also provides a self-reporting atmosphere that will enhance self-efficacy—a core element for intrinsic motivation and self-motivated learning (Jordan & Mitchell, 2015; Baker & Smith, 2019; Gligorea et al., 2023).

Integrating AI with education has the advantages of not only personalizing learning experience but also managing administrative tasks and monitoring learning progress (Zhao et al., 2019). Teachers using AI can obtain detailed reports on student progress and pinpoint learning gaps, allowing for interventions that are more specific and timelier (Wu et al., 2020; Luckin et al., 2016; Druga et al., 2022). Thirdly, by utilizing intelligent tutors and powerful algorithms, more complex projects can be handled by altering resources and content difficulty based on needs, increasing student autonomy and engagement for all stages of the project (Dahmen et al., 2020; Jordan & Mitchell, 2015).

Still, according to some authors, using AI in educational settings could create other issues related to dependency on personal information and the over-automation of some educational steps, which could compromise certain quality levels of educational interactions (Zawacki-Richter et al., 2019; Ito et al., 2021a; Lester, 2021). Technical infrastructure and digital literacy among educators play a decisive role in responding to these challenges and successfully introducing AI into PBL. Countering these types of challenges requires both pedagogical and technically sound steps to infuse AI in PBL to not to restrict pedagogical benefits with operational and technical aspects (Elsayary, 2024).

The aspects of AI integration that would have an impact on pedagogy, teachers' digital competency, and educational practices have been explored to understand whether there are significant differences between AI-integrated PBL vs. traditional PBL for teachers to reflect on their perceptions of AI in PBL. Based on the results obtained in this study, this research seeks to support the creation of a PBL pedagogical model optimized through AI, with a prior basis in previous studies of the active methodologies of educational technology and in accordance with effective ethical and pedagogical practices in pedagogical contexts in educational spaces.

To reach this goal, the following research questions were answered:

1. Do teachers believe that PBL enhanced through AI is more efficient when it comes to student engagement and learning outcomes than traditional PBL?
2. What are the main challenges and obstacles for teachers using AI in PBL?
3. How are AI tools affecting the degree of personalized learning available, and how does this impact student motivation throughout PBL activities?

Through these questions, the following hypothesis was proposed, which was the main objective of this research:

H1: *"Project-based learning (PBL) with artificial intelligence (AI) is perceived positively by teachers because it enhances personalization, motivation, and learning effectiveness compared to PBL without AI."*

2. Materials and Methods

A quantitative, comparative design process was conducted with a 5-point Likert scale questionnaire evaluating crucial elements such as perceived effectiveness, student motivation, and learning personalization with and without AI. This method allows for an in-depth analysis of potentially sizable inequities among groups of variables. VB1, teacher perception and the impact of AI integration in PBL, and VB2, teacher perception and the impact of traditional PBL use without AI, were the two variables that were examined.

A total of 300 teachers from three learning stages of education were included, encompassing primary (40%), secondary (30%), and higher education (30%) teachers. These teachers served in a variety of classrooms, including public and private schools, as well as urban, suburban, and rural schools. In terms of their field of study, the samples consisted of teachers in exact sciences, human sciences, and biological sciences. Although we did not collect exact data on the distribution of the disciplines, we can conclude that the wide representation of fields brings a varied perspective on the use of the AI methodology in PBL. In primary education, teacher specializations were often multidisciplinary; in secondary and higher education, their specializations were more subject-oriented. Participants ranged from 25 to 60 years old, with a mean age of 46 years, representing a good balance of early-career and experienced teachers.

For about five months, the teachers led experiences implementing project-based learning (PBL) according to its traditional approach. Next came another five consecutive months, a full school year later, of project-based learning (PBL) through the lens of artificial intelligence (AI), similar to the experience adopted by Kim (2023) in Korean university. This way of using AI in PBL maintained the same order and goals set earlier for classical PBL. In relation to teacher training, educators were provided with clear guidelines and sequences to integrate AI into their projects:

1. Choose and develop the initial PBL project.
2. Select a set of AI tools useful for that PBL project.
3. Explain to students the objectives and how to use these tools.
4. Evaluate and review the designed products with AI.

Additionally, including AI actively contributed to and mediated feedback loops, enabled a formative peer self-assessment of prototypes, and assisted the development of final products, as could also be noted in PBL in the absence of AI.

In two practical phases, this study was conducted to ensure the data collected reflected both the experience and perceptions aligned with a more accurate model of teaching practice:

- First phase (PBL without AI): Over a few months, teachers used a traditional PBL methodology with no AI, paying particular attention to planning, execution, and assessment. Additional support was offered to ensure practices were standardized and that there were no extreme differences in implementation not related to AI use. Students were guided by teachers as they defined the problem, researched independently, devised a hypothesis, and reported their findings.
- Second phase (PBL with AI): In this phase, teachers integrated AI tools into the established phases of project-based learning (PBL), including lesson preparation, personalization, and assessment. Unlike traditional PBL phases where feedback, assessment, and prototyping were only teacher-driven, in the AI-enhanced PBL phase, adaptive technologies offered real-time personalized feedback and enabled the automated assessment of prototypes. This integration improved the efficiency and personalization of the learning process.

This stage allowed us to assess the effects of the AI tool when used in the teaching and learning process of PBL. Training was implemented uniformly to ensure that each teacher had sufficient knowledge to implement AI in PBL effectively, having the following as objectives:

- To learn and apply artificial intelligence tools for learning such as Grammarly, GenAI, Canva with Magic Design, and Khan Academy.
- To begin or continue training in the use of artificial intelligence in education and PBL.

The training, which lasted two weeks and was conducted prior to the implementation of the second phase, covered orientation on the AI tools, their abilities, and how to incorporate them into the PBL structure. Each of these sessions was tailored toward the teacher's previous exposure to AI, making sure that no matter what level they started at, they obtained the same information. These training sessions lasted approximately three months with several sessions per week. A practical case from one of these sessions dealt with the use of Canva with Magic Design to create infographics with the help of AI. In this way, teachers learned how to use this tool to apply it and use it as a facilitator in the making of a final product in different learning situations or challenges posed to students, as well as using it as a tool to evaluate their prototypes.

Regarding these training sessions, teachers were very pleased to discover tools that facilitate their work and that of their students, as well as being able to improve the quality of their creations, taking generative AI tools as a reference for the possibility of creating images, text, and even audio.

Additionally, teachers were provided with support materials and were encouraged to contact the research team for technical assistance throughout the second phase of this study. This aligns with Alreshidi and Lally (2024), who emphasized the importance of teacher training in PBL.

Polls were conducted in public and private universities based in urban, suburban, and rural areas to provide diverse representation. Teachers were involved in this study for one academic year, with each phase (PBL no AI and PBL AI) lasting around five months. During the implementation phase of AI, teachers were trained and supported to standardize the tools' use and reduce variability in the tools' implementation.

Teachers received the questionnaire electronically, sent through SurveyMonkey, and were also informed on informed consent and how to access the form and fill it out online.

The teachers' perceptions were evaluated in numerous areas of PBL according to the findings of the survey:

- Perception of AI-enhanced PBL: We intended to evaluate the perceived effectiveness of AI within PBL with respect to personalization, adaptability, and assistance in the learning process. Some questions were as follows:
    - "How effective do you perceive AI to be in improving students' motivation in PBL activities?"
    - "How is AI improving personalized learning in PBL as opposed to traditional approaches?"
    - "How did AI influence your teaching: did you have a heavier or lighter workload?"
    - "How did you improve teaching quality and time by using AI?"
    - "How did AI in PBL influence student success?"
- Student motivation: Teachers' perceptions were collected regarding the differences in student motivation and decreased anxiety created by the provision of real-time feedback when integrating AI within PBL, as opposed to traditional PBL without AI integration. In line with Mohamed et al. (2024), these findings highlight the potential of AI to empower students. The questions of the survey reflected how teachers perceive these effects on their students. Some questions were as follows:
    - "Do you feel that thanks to the immediate feedback from AI, your students' anxiety about knowing the outcome of their PBL project is reduced?"
    - "Do you think your students' anxiety about knowing the achievements of their work in a shorter space of time has reduced?"

- "Do you believe that using AI in your student's learning improve their motivation?"
- "Do you feel that your students are more motivated towards a PBL project that incorporates AI or one that does not incorporate it?"
- "Would you say that AI improves your students' motivation and reduces their anxiety?"

- Perception of PBL without AI: We assessed teachers' general satisfaction and overall opinion of PBL without any type of AI used to assist or support PBL. Some questions were as follows:
  - "Do you think incorporating AI technology into PBL is necessary and increases the quality of learning?"
  - "Is PBL without AI seen as an old method relative to using PBL with AI?"
  - "Do you think feedback from PBL without AI can be just as fast as with AI?"
  - "Do you think learning is more current in PBL without AI?"
  - "Do you think student motivation for a PBL project without AI is lower?"
- Implementation challenges: We captured teachers' perspectives on potential deprivation, the availability of the generating infrastructure, and digital training needs to adopt AI implementation in PBL vs. PBL implementation without the use of AI. Some questions were as follows:
  - "Do you think schools currently have the infrastructure needed to address learning with AI?
  - "Do you think that more training is needed for teachers to be able to transfer the use of AI in PBL to their students learning?"
  - "Do you think that there is a long way to go in terms of improvements and implementations to achieve good use of technology?
  - "Will better digital teacher training improve the quality of learning?"
  - "What are the most significant changes that educational centers must do in relation to this issue?"

This questionnaire, associated with a 5-point Likert scale, where it addresses specific descriptions for each value, measures teachers' perceptions of AI in PBL:

1. Strongly disagree (1): The teacher feels the opposite of the statement about AI in PBL, or it does not apply to them at all, for example, "AI does not personalize learning".
2. Disagree (2): The statement is perceived by the teacher to be mostly negative, or it does not align with their perception significantly, for example, "I do not think that AI is meaningful to promote student motivation in PBL".
3. Neutral (3): The teacher has no strong opinion or thinks that the statement is sometimes true for them, for example, "I don't know if AI increases student motivation".
4. Agree (4): The teacher perceives that the statement is mostly positive and aligns with their perception, for example, "I think AI is helping us personalize learning, especially in PBL".
5. Strongly agree (5): The teacher sees the statement as very positive and a perfect fit to their experience or perception of artificial intelligence in PBL, for example, "I am completely convinced of how AI increases motivation and personalization in PBL".

The surveys were administered to teachers in public and private schools across urban, suburban, and rural areas to ensure diverse representation. The teachers took part in this study for an entire academic year.

In this study, a validated questionnaire was used for data collection from respondents. Initially, we consulted with a panel of experts in educational technology (7), pedagogy (7), and assessment (7) to review the relevance, clarity, and structure of the questions.

After involving experts who provided objective feedback regarding the content of the instrument, a pilot study was conducted where a small group of teachers was invited to test the instrument, evaluating the reliability and understanding of the instrument. Slight modifications were made to verify the structure and validity of the questions based on the pilot study's findings. The questionnaire was then finalized and circulated among the full sample of teachers.

The data were collected, and detailed statistical analyses for obtaining a better understanding of the different responses were performed using IBM SPSS Statistics.

1. Descriptive Statistics: These were calculated to assess the central tendency (mean) and dispersion (standard deviation) of teacher perceptions within each group (with and without AI), offering an initial view of the potential differences in the two methods.
2. Shapiro–Wilk Normality Test: This test was performed to test the perceptions in each group for normal distribution and was a precondition for conducting Student's *t*-test. The constructs of normality validated the appropriateness of parametric tests and bolstered the accuracy of inferential outcomes.
3. Levene's Test for Equality of Variances: This test was conducted to test whether the assumption of equal variance in Student's *t*-test holds.
4. Mann–Whitney (U test): Since data did not follow normality assumptions, the Mann–Whitney U test was applied. This non-parametric test enabled the comparison of perceptions between the groups.
5. Effect Size: To further elaborate on the difference between PBL with AI and PBL without AI in the context of the Mann–Whitney U test, effect size was calculated, providing additional insights into the practical significance of the results.

A significance level of 0.05 was defined for all analyses.

3. Results

This study seeks to evaluate the perceptions of 300 primary, secondary, and higher education teachers in the debate regarding the inclusion of artificial intelligence (AI) in project-based learning (PBL) and traditional methods. The results are reported based on the descriptive and inferential analyses performed.

The descriptive statistics indicate the overall distribution of the teachers' perceptions within each of the groups with and without AI integration in PBL. The central tendency and dispersion features for each group are presented in Table 1. The average perception score in the AI-integrated group was 4.17 (standard deviation = 0.47), but in the group without AI, the mean was 3.49 (standard deviation = 0.57). Also, there was no overlap of the 95% confidence intervals for the mean for each group, which indicates a significant difference between the two conditions.

The positive difference in the means suggests that the integration of AI in PBL is perceived by the teachers as a factor that is likely to contribute to a better learning experience than that obtained with the traditional method. The smaller standard deviation found in AI-integrated PBL hints towards a more homogeneous and better perception among individual teachers that are acquainted with this new methodology, teach it, or evaluate it.

The normality of distribution of the perceptions of the teachers was tested in both groups using the Shapiro–Wilk test. As shown in Table 2, the group with AI present did not follow the normality assumption ($p = 0.004$); however, the group without AI did not show significant deviation from a normal distribution ($p = 0.373$).

Table 1. Descriptive statistics.

Descriptives					
	Method Code			Statistic	Std. Error
Perception	1	Mean		4.17	0.03
		95% confidence interval for the mean	Lower bound	4.12	
			Upper bound	4.23	
		5% trimmed mean		4.18	
		Median		4.16	
		Variance		0.22	
		Standard deviation		0.47	
		Minimum		2.89	
		Maximum		5	
		Range		2.11	
		Interquartile range		0.65	
		Skewness		−0.23	0.14
		Kurtosis		−0.41	0.28
	2	Median		3.49	0.03
		95% confidence interval for the mean	Lower bound	3.43	
			Upper bound	3.56	
		5% trimmed mean		3.49	
		Median		3.54	
		Variance		0.33	
		Standard deviation		0.57	
		Minimum		1.67	
		Maximum		5.	
		Range		3.33	
		Interquartile range		0.75	
		Skewness		−0.07	0.14
		Kurtosis		0.29	0.28

Table 2. Shapiro–Wilk normality test.

Normality Test				
	Method Code	Shapiro–Wilk		
		Statistic	df	Sig.
Perception	1	0.98	300	0.00
	2	1	300	0.37

The abnormality in the AI group might vary in perceptions due to idiosyncratic perceptions, such as the experiences with technology of different teachers or exposure to AI environments. In comparison to the normally distributed nature of the group without AI, this variance indicates a broader spectrum of sentiments about AI implementation in PBL. Given the apparent diversity of perceptions within the AI group, it could be assumed that teachers have a critical view or, on the contrary, a very, very positive view of AI, and this could be affected by the educational level at which a respondent taught or their professional experience.

To assess differences between teachers' understanding of integrating AI in PBL and the conventional method, descriptive statistics were computed for both types. In the AI-

embedded group, the mean of perception was 4.17 (standard deviation = 0.47), while in the non-AI group, it was 3.49 (standard deviation = 0.57) (Table 3). Thus, there is a generally more favorable view of AI integration into PBL, as implied by these initial differences.

Table 3. Group statistics.

Group Statistics					
	Method Code	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Perception	**1**	300	4.17	0.46	0.03
	2	300	3.49	0.57	0.03

Figure 1 illustrates the distribution of teacher perceptions within each group using a boxplot to display the median, interquartile ranges, and outliers for each group. This indicates that the median perception and data dispersion were relatively greater than average in the groups integrated with AI with respect to the groups not integrated with AI.

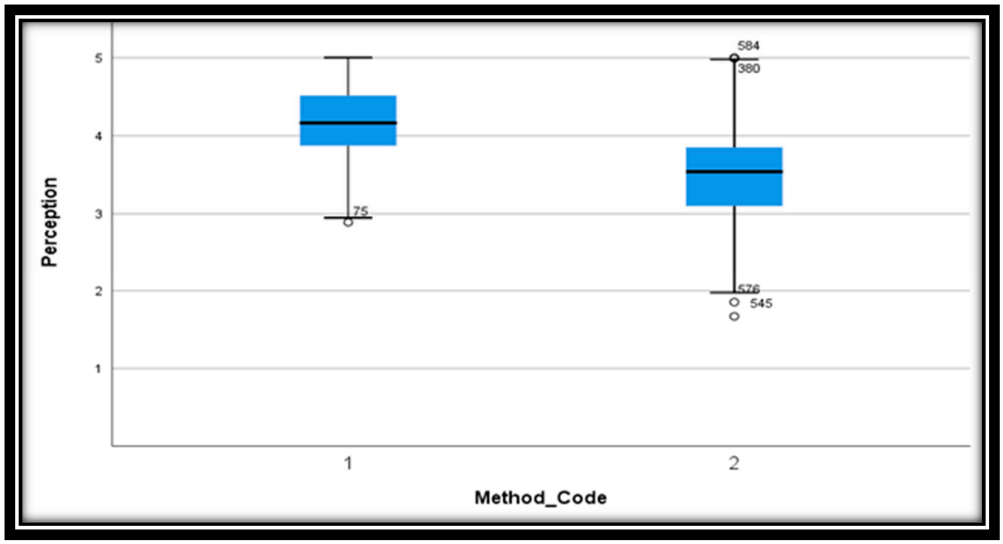

Figure 1. Boxplot of teacher perception by method code.

Visually, this graph serves to reinforce the difference revealed through statistical tests: there is a greater median perception in the AI group compared to the non-AI one. However, as shown in this figure, the AI group is less dispersed, with the interquartile range being narrower, implying that teachers had a more consistent positive perception of AI-assisted PBL. This, in turn, substantiates the interpretation of AI being viewed as a useful tool in the teaching process with a significant association in qualitative data, as its use is considered valuable in the PBL context due to the potential to personalize and enrich learning.

A Mann–Whitney U test for independent samples was performed to assess whether this difference in likelihood perception was statistically significant between both groups. We chose this non-parametric analysis approach because of the shape of the data distribution. These results suggest that integrating/not integrating AI into PBL results in a statistically significant difference in perception. The standardized test statistic was $Z = -13.69$, confirming the additional evidence implying the presence of a significant difference between the perception of PBL with AI and the perception of PBL without AI. This evidence leads to the conclusion that teachers hold considerably more positive than negative views about the impact of AI on PBL.

Finally, to quantify the observed differences, the effect size (r) for the Mann–Whitney U test was computed and is shown in Table 4. The outcome was r = 0.56, which would be considered a large effect according to most classification systems. Such a great effect size suggests that AI tools have effects that are, for a teacher, highly favorable in the PBL model. This finding indicates the practical value of AI-enhanced educational innovations and highlights the importance of such tools in real-life conditions. This not only emphasizes the presence of a considerable difference in teachers' perceptions but also suggests that there are practical implications of AI in PBL for future implementations and research in such methodologies.

Table 4. Mann–Whitney U test.

Mann–Whitney U Test	
Total N	600
Mann–Whitney U	15,924.0
Wilcoxon W	61,074.0
Test statistic	15,924.0
Standard error	2123.08
Standardized test statistic	−13.69
Asymptotic significance (two-tailed test)	0.00

The results provide deeper insights into the statistical analyses of these questions, indicating the range and divergence in the views held by teachers of various educational levels on the role of AI and its use in the PBL methodology. In general, these results suggest a propensity for the use of AI in PBL that is far more positive and cohesive among teachers based on the context of the implementation or review of the use of AI in PBL.

4. Discussion

This paper illustrates how teachers view the use of AI in project-based learning. This study shows that teachers have positive attitudes towards the use of AI in project-based learning and AI's ability to further improve project-based learning compared to traditional project-based learning. Positive findings regarding AI in education are emerging from some studies. In one study carried out by Su (2022), AI-based natural science learning environments enhanced students' motivation, performance, and problem-solving abilities in collaborative learning. These results support this perspective, showing that teachers view AI as a form of assistance that aids project efficiency but also allows for instruction tailored to student needs.

These insights then went on to inform the findings of the current study, which in turn elucidated the contributing factors that enhance the effectiveness of PBL, which in turn informed the development of an AI-optimized pedagogical model. Teachers said that adaptive feedback and real-time self-assessment tools are helpful to reduce students' anxiety and motivate them. This is supported by Wang et al. (2022), who explored how anxiety levels can be affected by AI. Although this study did not directly assess anxiety reduction, previous research highlighted it as an important point in increasing students' confidence, and it may be an element of research for future work. This indicates that the integration of AI in the PBL framework enhanced motivation, personalization, and learning outcomes, which is also in line with earlier studies (Alhafidh, 2024; Su, 2022). Insights like these are important for designing models based on AI to enhance active learning approaches.

In previous research, the advantages of AI through separate educational stages were analyzed. Context-aware engagement is particularly significant in online learning environments. For instance, Ito et al. (2021b) explored the application of AI, such as chatbots, in a Japanese PBL setting focused on self-directed learning without direct instruction. This methodology was particularly beneficial during the COVID-19 pandemic crisis when students could not attend physical classes, highlighting one more benefit of AI as it helps enhance active learning while working in remote/virtual scenarios. This was not a virtual study, yet teachers responded that both adaptive feedback and the series of automated feedback provided, like those found in online studies, led to the ability to continually make the learning process more deliberately focused on improvements independent of the context.

Research by Wu et al. (2020) investigated the application of AI in a medical problem-based learning (PBL) context and found that the implementation of AI in a problem-based learning process can significantly enhance student performance and the satisfaction level in the medical diagnostic domain. This study noted the AI aspects of enhancement along with deep learning and building student confidence, very important factors for building high-level competencies in students. The results of this research help strengthen such outcomes, as teachers perceived and improved students' autonomy and motivation towards the use of AI-supported PBL, pointing towards the significance of this technology for competency development and soft skill growth.

Moreover, an upcoming study by Kolmos et al., specifically, Kolmos et al. (2021), implemented problem-based learning (PBL) in engineering and examined enhancements in students' general skills including teamwork and problem-solving ability. But they added that while PBL has notable advantages in developing practical and collaborative skills, as well as social competences, some students said that they feel less prepared in terms of domain-specific competencies in natural sciences. The findings suggest that the use of AI improves not only general competencies but also specific technical ones in PBL, which could be a method for overcoming the limitation identified by Kolmos and his team through customization for appropriate competencies in each field of knowledge.

Many of these hurdles are well documented in the literature and include insufficient infrastructure, technical training, and the ability to implement advanced technologies (Salas-Pilco et al., 2022). A systematic and collective review of the implementation of artificial intelligence (AI) and learning analytics in teacher education concludes that technologies for learning help mirror the fact that teachers should only use technologies for learning with obtained advanced digital competencies. These competencies are viewed as important for the successful integration of AI into the educational landscape. These conclusions match the results of this research, which stated that the absence of certain training and infrastructure is a barrier to the reliable use of AI in PBL. Furthermore, teachers in low-tech contexts may experience further issues in using technology and therefore in optimizing AI to improve the advantages that are offered to students, something else that future paths for education should focus on.

The effect size we found indicates that AI had a strong effect on teachers' perceptions of PBL. As Khan et al. (2024) found in a pioneering study on experimenting with AI in project-based learning (PBL), AI in PBL increased not only the effectiveness of education but also the motivation and collaborative learning of students. While Khan et al.'s study focused on student outcomes, our results highlight the significant influence AI can have on teachers' perceptions of PBL. This finding supports recommendations for the integration of AI in an applied learning setting, facilitating AI as a motivating tool and facilitator of interaction in active learning.

Additionally, the integration of agile methodologies with PBL has proven equally effective. Barros et al. (2023) found that the integration of agile methods like Scrum in PBL enabled better AI education in computing as compared to traditional methods, with students not only developing better teamwork skills but critical thinking strategies too. This indicates that the application of methodologies such as Scrum and AI in PBL could further facilitate collaboration and analysis abilities in students, furnishing a transparent yet adaptable framework that promotes self-directed and deep learning.

Additionally, this work highlights teachers' positive perceptions of the use of AI in PBL, as the use of this tool has possibilities to not only enhance learning but also improve a pedagogical design previously developed without the use of AI. Although the use of PBL without AI is well received by teachers, their perceptions are much more favorable for the AI-supported model. This is evidenced not only by all the collected data and findings but also by the results of their perceptions which highlight the positive characteristics of AI in PBL.

This study articulates the considerable advantages of integrating AI into project-based learning (PBL), but it is important to recognize that there are challenges, concerns, and areas for caution. A significant concern is the risk of over-reliance on AI systems, which cannot replace the human interaction crucial for pupils' overall development and the promotion of soft skills such as empathy and teamwork, according to Zawacki-Richter et al. (2019). Moreover, the actual deployment of AI itself entails significant investment in both system infrastructure and teacher training, which may not be uniformly achievable across all educational contexts, especially within under-resourced and underfunded institutions.

Data privacy and ethical concerns relating to the use of AI in education are other aspects we need to keep in mind when deciding to use AI in the conventional educational system. Mutawa and Sruthi (2023) previously showed that there is a need to address how large datasets are collected, how they are intended to be used, and how they are stored to enable AI-driven personalization. Dealing with these and other similar issues involves strong data protection policies and open communication with relevant parties.

Finally, it is important to find the middle ground between what AI is capable of and traditional pedagogical approaches. However, if not conducted carefully, the over-automation of PBL processes could potentially take away students' autonomy and ability to think critically. In conclusion, these elements highlight the importance of a careful and measured approach to incorporating artificial intelligence into educational settings.

5. Conclusions

To summarize, this study indicates the potential positive outcomes of the integration of AI into PBL, enhancing teachers' learning experience and personalization perceptions. This review provides valuable insights into the different design guidelines and performances of AI in PBL, and a general trend is detected compared to earlier studies that exist in the literature with respect to AI utility; AI in PBL is helpful in acquiring both technical and overall skills and facilitating self-directed and adaptive learning. However, AI's actual application in certain environments is limited by infrastructure and teacher training issues. Subsequent studies can not only focus on how AI can be a factor in reducing student anxiety but also consider implementing AI as new instructional practice that fosters and complements 21st-century skills—which can be considered as both a skillset and mindset—so that AI is much more relevant and holistic in terms of 21st-century knowledge, skills, and competences in society.

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