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Evaluating the Efficacy of Project-Based Approach for Teaching Humanities Courses to Engineering Students

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Evaluating the Efficacy of Project-based Approach for Teaching Humanities Courses to Engineering Students

Abstract

This paper investigates the effectiveness of a project-based learning (PBL) approach for integrating humanities education into the engineering curriculum. To test the effectiveness of the PBL approach, first-semester and third-semester engineering students enrolled in the course titled “Entangled Worlds: Technology and the *Anthropocene*” were exposed to many concepts from humanities. The course curriculum was designed to integrate humanities and engineering to understand the havoc wreaked on the planet by human activity and technologies (called the age of the *Anthropocene*), and reimagine our present technologies for a better future. The course was jointly developed and simultaneously delivered by two faculty representing humanities and engineering domains respectively. This was done so that the students could appreciate both the philosophical and theoretical frameworks from the humanities governing the scholarly literature on the *Anthropocene* while at the same time gaining an understanding of statistical data and scientific evidence establishing the detrimental effects of present-day technologies. It was felt that humanities could be best learned by engaging the engineering students through a PBL approach.

The students grappled with current real-world problems and reimagined technological solutions for a sustainable future with the planet as a stakeholder (the *Planetocene*) through projects. The PBL approach was also compared to a traditional lecture-based humanities course RTS (Reimagining Technology and Society) taught previously to the current third-semester students.

Students performed significantly better ($p < .001$) in the PBL-incorporated course compared to the RTS course, demonstrating the effectiveness of PBL in enhancing learning outcomes. While both groups rated the course highly, students with no prior humanities coursework (Semester 1) had a slightly more positive perception ($p < .05$) and performed slightly better ($p < .001$) than those with prior exposure to a traditional humanities course experience (Semester 3).

Thus, we conclude that PBL can offer a promising approach for bridging the humanities-engineering divide, cultivating critical thinking skills, and preparing future engineers to tackle planetary challenges. However, the potential benefits of PBL may be maximized when implemented with students who have not yet received extensive traditional humanities instruction.

Keywords

Project-based Learning, Learning Environments, Humanities, Engineering Curriculum, Pedagogy

Introduction

Engineering students often perceive themselves as existing in distinct academic spheres from their humanities counterparts. They may harbor concerns about navigating unfamiliar pedagogical approaches, expectations, and entrenched stereotypes surrounding the "engineering vs. Arts" divide [1]. As Zavarzadeh and Morton [2] suggest in their work "Theory Pedagogy Politics: The Crisis of 'The Subject' in the Humanities," navigating theoretical pedagogy, a mainstay in humanities education, can be particularly daunting for students, especially engineering students, who are unfamiliar with its nuances. They underscore the tensions inherent in theoretical approaches, highlighting the potential for students to feel alienated by overly abstract concepts while teaching humanities.

Allsopp [3], in his work "Bridging the Gap between Theory and Practice: Connecting Courses with Field Experiences" argues for embracing new modes of thought and digital tools to bridge this gap and create a more engaging learning experience for students. He acknowledges the potential disconnect engineering students may feel between theoretical pedagogy and their preferences for active learning approaches. These ideas resonate with the current need to move beyond traditional theory-based pedagogy used in teaching humanities to engineering students and create a learning environment that aligns with engineering students' preferences.

This paper details our efforts at Plaksha University, an engineering university in Punjab, India to effectively integrate humanities into the engineering curriculum. Our initial attempt, a one-credit course titled "Re-imagining Technology and Society (RTS)," employed a theory-based lecture delivery pedagogy. However, this approach fell short in capturing the interest of engineering students.

Thus, incorporating the feedback from our previous course and replacing our pedagogy with a PBL approach, we implemented a redesigned interdisciplinary course titled "*Entangled Worlds: Technology and the Anthropocene* — Ushering the *Planetocene*: New Humanity and Post-*Anthropocene* Technologies." The term *Anthropocene* is proposed and increasingly employed to denote the current epoch in which human activity has a dominant effect on the planet [4]. The term *Planetocene* is a concept that envisions an era where the primary focus is on prioritizing the needs and well-being of our planet as a whole. Ushering in the *Planetocene* is a call to action for a collective, global commitment to safeguard our planet's natural systems and ensure a harmonious coexistence between human species in societies and the broader biosphere.

This course, co-designed by faculty from both humanities and technology backgrounds, leverages the expertise and perspectives of each discipline. We postulated that perhaps a Project-based learning (PBL) approach would be more effective as pedagogy to teach concepts from humanities to engineering students. This is also echoed by previous research that substantiates the role of the PBL approach as an effective pedagogy for such course materials as the learning preferences of engineers since they tend to gravitate towards project-based learning (PBL), problem-solving activities, and real-world applications [5]-[6].

To assess the effectiveness of the PBL pedagogical approach, as opposed to the traditional reliance on written reports prevalent in humanities courses, we utilized statistical measures, end-of-course student feedback surveys to gauge student course perception, and evaluations of project submissions to evaluate student performance in the course.

This paper explores the challenges and strategies associated with using a PBL approach in integrating humanities into engineering education. We present the findings of introducing a redesigned interdisciplinary course that strives to achieve a balance between 'art and techne' [7]. The aim of the course was to uphold the critical and theoretical foundations of a humanities education while maintaining a strong emphasis on rigor and practical applications required by engineering students.

The evaluation of the outcomes of this pedagogical experiment will help shape discussions on promoting the PBL approach, particularly in engineering studies. Finally, our paper aims to offer new insights and recommendations for educators and institutions seeking to cultivate well-rounded engineers equipped with both technical expertise and a nuanced understanding of the humanities.

Background

Engineering education traditionally emphasizes the development of strong problem-solving skills. This focus is reflected in the 2004 US National Academy of Engineering report, "The Engineer of 2020: Visions of Engineering in the New Century," which links engineering with technology and the identity of engineers as technical problem solvers [8]. This requires engineers to break down large complex problems into smaller, more manageable parts [9]. By breaking down complex problems into manageable parts, engineers can identify the technological aspects of societal challenges. This allows them to focus their problem-solving skills on these technological components, ultimately developing solutions that improve the quality of life for humankind.

In other words, "engineering is problem recognition, formulation, and solution" [8]. This problem-solving approach positions engineers as much-needed consultants to society. Similar to how a consultant responds to a client's needs, engineers are called upon to address societal challenges through innovative and effective technological solutions. For instance, in the face of potential disasters, engineers might be tasked with minimizing risks, creating backup solutions, and facilitating rapid recovery efforts [10].

However, while strong technical expertise remains essential, the current challenges of the planet necessitate a more nuanced understanding of the relationship between technology, society, and the environment. In response to this, engineering education, specifically in the environmental engineering landscape, is undergoing a metamorphosis, acknowledging the importance of cultivating well-rounded graduates capable of empathizing with the needs of the planet [10]. This requires equipping engineering students with strong critical thinking and reading abilities, traditionally nurtured by a liberal arts background [11]. In 2000, the Accreditation Board for Engineering and Technology (ABET) echoed this sentiment in its requirements, highlighting the significance of teaching humanities courses to engineers [12]. This interdisciplinary approach is crucial for developing a greater degree of critical reflexivity concerning nature-human-technology relations. However, integrating humanities courses into an already jam-packed engineering curriculum remains a persistent obstacle [13].

The integration of humanities into engineering education often faces challenges due to the prevalence of traditional teaching methods and a lack in pedagogical innovation. As highlighted by Feldt and Petersen [14], educational institutions can be resistant to change, lagging behind in responding to the evolving needs of engineers to adapt to the broader world issues such as climate change, globalisation, etc. which have wide-ranging impacts on the economy, culture, and society.

A key characteristic of traditional humanities courses is their reliance on teacher-directed curriculum and lecture-based instruction [15]. This approach, while familiar to many humanities professors who report spending a significant amount of time on teaching [16] can be less engaging for engineering students. More importantly, these traditional methods of lecture delivery often fail to cultivate the essential "Engineering Habits of Mind (EHoM)" required for success in the modern engineering landscape. EHoM represents a set of core skills and mindsets such as systems thinking, adapting, problem-finding, and creative problem-solving that distinguishes engineers from other professions [17].

Therefore, the use of PBL in teaching humanities courses offers a promising approach to equip future engineers with these crucial skills and the necessary mindset to develop sustainable and equitable solutions for the future. By engaging in projects, engineering students learn to grapple with real-world, multidimensional challenges, to adapt and innovate—a crucial mindset for addressing the multifaceted issues faced by engineers [18].

One of the early definitions for PBL [19] involves five distinct aspects: a) student-driven problem-solving where they propose their problems or choose from options, fostering ownership and engagement, b) integration of a range of educational activities, c) a tangible deliverable outcome, such as a presentation, prototype, or research report, demonstrating their understanding, d) solution is part of the project framework and involves sustained effort, and e) shifting instructor role: instructors transition from authority figures to supportive consultants, guiding and facilitating student learning [18].

Scholars view PBL as an excellent Means to encourage self-learning and interpersonal interactions among students [20]. It aligns with technological instruction requirements, providing students with more opportunities for higher-order cognitive processes [21]-[22]. However, the implementation of PBL in large classrooms presents challenges, including difficulties in promoting student motivation, maintaining focus on learning tasks, connecting new content with prior knowledge, and efficiently conducting cooperative learning activities [23].

By teaching interdisciplinary courses such as "Entangled Worlds: Technology and the *Anthropocene*" that explore the relationship between Technology and the *Anthropocene*, for example, engineering students are compelled to critically examine the relationship of the *Anthropos* (humans) with nature and technology. Such courses encourage critical reflection and can equip engineers with the necessary mindset to develop skills like systems thinking and problem-finding [24].

While research on project-based learning (PBL) in engineering education has grown, less attention has been paid to the use of PBL in teaching humanities courses to engineering students in interdisciplinary contexts.

This paper addresses this gap by examining PBL as a pedagogy to integrate humanities in an engineering curriculum and encouraging students to weave together perspectives from both humanities and the sciences. By analysing survey feedback and project submissions, we aim to measure the efficacy of the PBL approach in teaching humanities to the engineering fraternity.

Research Questions

1. How are student learning and performance affected when a project-based approach (PBL) is used to teach humanities to engineering students?

2. Does previous exposure to humanities taught using conventional pedagogies have any effect on engineering students' perception of humanities courses taught by the PBL approach?

3. Does previous exposure to humanities taught using conventional pedagogies have any effect on engineering students' actual course performance taught by the PBL approach?

Our goal is to identify insights into optimizing the PBL design and implementation for enhanced learning experiences and outcomes in teaching a humanities course to engineering students.

Methodology

Participation

A total of 232 engineering students (137 from the first semester and 95 from the third semester; 159 male, 73 female) of Plaksha University, a technological university in Punjab, India constituted the participants.

Procedure

Data was collected in three stages:

1. Student performance data was collected of the current third-semester students for their two humanities courses titled "Re-imagining Technology and Society (RTS)" (delivered between January-May 2023) and "Entangled Worlds: Technology and the *Anthropocene*" (delivered between October-November 2023). The course performance of the former was considered the control group while the course performance of the latter was considered the experiment group as this course was taught using a PBL approach.
2. Student performance data was also collected when the first-semester students took the course "Entangled Worlds: Technology and the *Anthropocene*" to compare it with the performance of third-semester students. These first-semester students had previously never been exposed to humanities courses since middle school.
3. Finally, an end-of-course survey was conducted to gauge the student perception of the course "Entangled Worlds: Technology and the *Anthropocene*" (which used a PBL approach) an online feedback survey. The survey was filled in by 159 respondents out of 232 students who took the course.

Course Module Outline

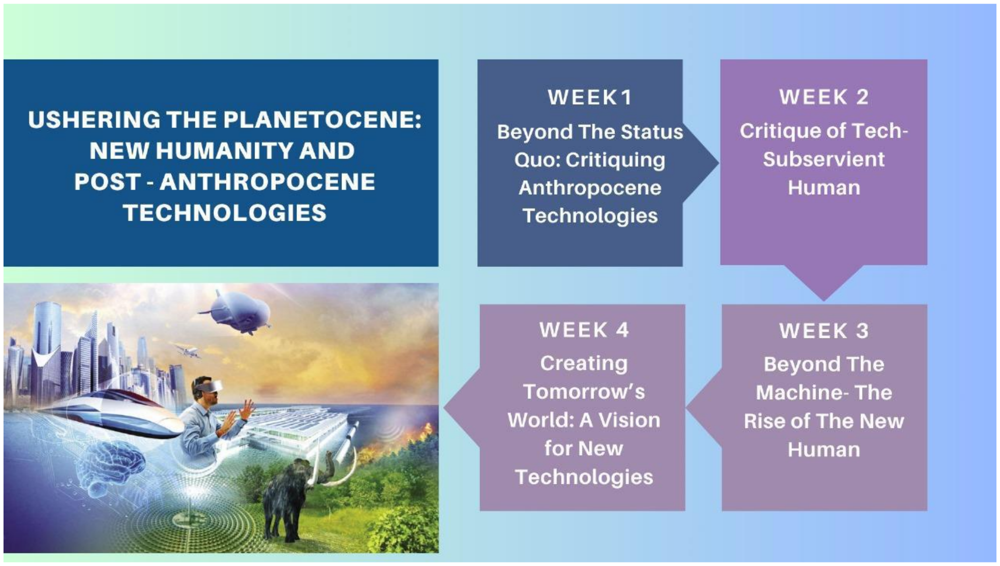

Fig 1. Ushering the *Planetocene*: New Humanity and Post-*Anthropocene* Technologies

Project Activities

Students took part in PBL in each lecture where they specifically did one component of the project which consisted of brainstorming and answering a few questions as a group. The guidelines and discussion questions for each week are given below in Table 1.

Table 1: Project Guidelines for the Course Module

Timeline	Guidelines
Week 1	• Form student groups of three for the Project Post-*Anthropocene* Technology (PAT) • Each student group selects one *Anthropocene* challenge to tackle through their project • 50-word submission in bullet points at the end of every class
Week 2	• Identify the technology & human thinking and societal structures contributing to the chosen *Anthropocene* problem • Provide a comprehensive critique of these elements within your project context
Week 3	• Identify the *Planetocene* thinking emerging within your project context, providing a detailed description of their relevance and implications
Week 4	• Collaborate on the development of post-*Anthropocene* technology solutions tailored to the chosen project

The final component of the project included submitting a 3-minute multimedia recording. It could be a video recording, a presentation (with a voiceover), or an animation (with narration) compiling the answers to the questions below and discussing the prototype of their new technological solution.

1. *What Planetocene technology would you like to work on and how does it make the planet a stakeholder?*
2. *How does this technology solve the problem of the Anthropocene?*
3. *How does this technology take into account reimagined human values and traits?*
4. *How does this technology critique old forms of thinking?*

Project-Evaluation Analysis

Based on the evaluation of videos submitted by the students as part of their final project submission, it was evident that the students were able to engage with the course critically and were able to understand a) the havoc caused by human activity on our planet in this age of the *Anthropocene*, b) how the technologies developed by us are not only shaping our planet but also our lives, c) we need to make our planet a stakeholder (*Planetocene)* as we embark on a mission to re-imagine our technologies to make them more responsible for the planet as a whole.

Some of the ideas that the students came up with in their project submissions were: a) Use of ocean fertilization to stimulate phytoplankton growth and enhance carbon sequestration, b) bio-plastics from algae, c) eco-mesh use in wall cladding, d) hydrogen fuel cells, and e) plant sound detection to develop empathy with nature for solving issues like deforestation.

Results

Third-semester students' performance in Entangled Worlds: Technology and the Anthropocene course (PBL approach) vs their performance in the previously taught RTS course (traditional humanities approach) wherein the maximum score was 30 for both subjects.

Table 2: Descriptives for Paired sample t-test

	N	Mean	SD	SE	Coefficient of variation
PBL	95	28.021	2.392	0.245	0.085
RTS	95	22.916	7.118	0.730	0.311

Measure 1		Measure 2	T	Df	P
PBL	-	RTS	6.866	94	< .001

Note. Students' t-test.

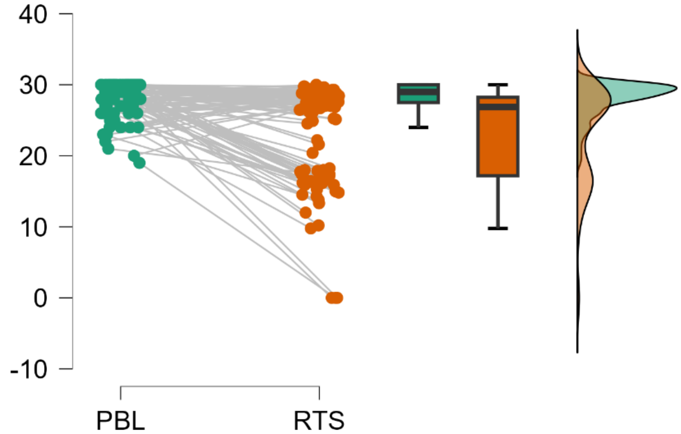

Figure 2: Student performance in the Entangled Worlds: Tech and the *Anthropocene* course using a PBL approach vs. the RTS course delivered using a traditional humanities approach

A paired samples t-test was done to see the difference in actual performance scores for the experiment and control trial. The results from the experiment trial (PBL) (Mean=28.021, SD = 2.39) and control trial (RTS) (Mean =22.916, SD = 7.18) indicate that there is a statistically significant difference in the actual performance scores between the two trials and students did better during experiment trial in comparison to the control trial $t(22) = 6.86$, $p < .001$.

The box-whisker plot also shows how most students did well when taught using a PBL approach compared to the RTS course where marks are distributed in two different clusters.

Course perception ratings out of 10 by Semester 1 vs Semester 3 students

This analysis examines student perceptions of the project-based learning (PBL) approach used in the course, based on end-of-the-course survey data filled by 159 students (96 from Semester 1, and 63 from Semester 3) out of a total of 232. Descriptive statistics were used to summarize student responses on a 0-10 Likert scale (0 = Pathetic, 10 = Excellent) across five key aspects of the PBL experience:

1. Effective delivery of central message (Mean = 6.51, Median = 7, Mode = 7, SD = 1.93)
2. Helped in navigating ideas (Mean = 6.34, Median = 7, Mode = 7, SD = 2.16)
3. Helped in making sense of the course (Mean = 6.33, Median = 7, Mode = 7, SD = 2.05)
4. Helped increase participation in the course (Mean = 6.33, Median = 7, Mode = 7, SD = 2.34)
5. Transformed thinking (Mean = 6.11, Median = 7, Mode = 7, SD = 2.32)

Table 3: Descriptives for an Independent samples t-test

	t	**Df**	**P**
Semester 1	2.124	108.222	0.018

Note. For all tests, the alternative hypothesis specifies that group *Sem1* is greater than group *Semester 3*.

Note. Welch's t-test.

	Group	**N**	**Mean**	**SD**	**SE**	**Coefficient of variation**
Semester 1	Semester 1	96	6.346	2.018	0.206	0.318
	Semester 3	63	5.514	2.642	0.333	0.479

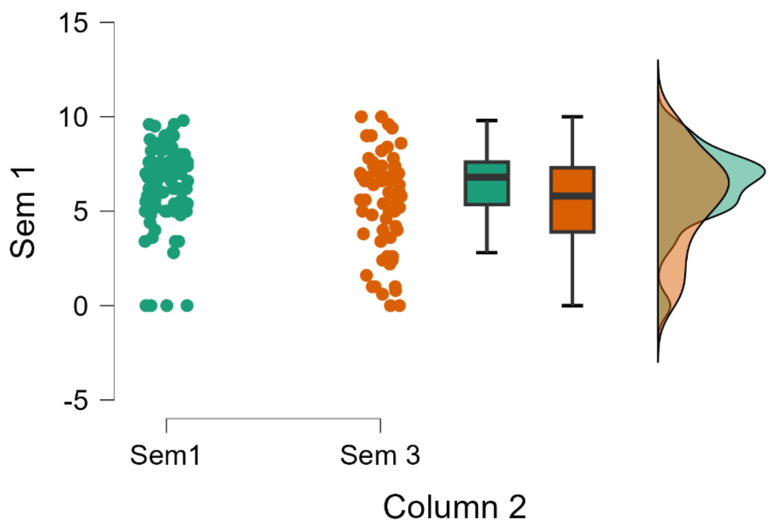

Figure 3: Course perception ratings out of 10 by Semester 1 vs Semester 3 students

An independent samples t-test was done to see the difference in course perception scores for Semester 1 and Semester 3 students. The results from Semester 1 (Mean = 6.34, SD = 2.01) and Semester 3 (Mean = 5.51, SD = 2.64) indicate that there is a slight difference in the course perception scores between two trials and Semester 1 students gave slightly higher course ratings in comparison to the Semester 3 students $t(22) = 2.124$, $p < .05$.

Actual marks scored out of 30 by Semester 1 vs Semester 3 students in Entangled Worlds: Technology and the Anthropocene course

Table 4: Descriptives for the Independent samples t-test

	t	**df**	**P**
Marks Scored	3.722	131.792	< .001

Note. Welch's t-test.

Group Descriptives

	Group	**N**	**Mean**	**SD**	**SE**	**Coefficient of variation**
Marks Scored	Semester 1	137	29.022	1.286	0.110	0.044
	Semester 3	95	28.021	2.392	0.245	0.085

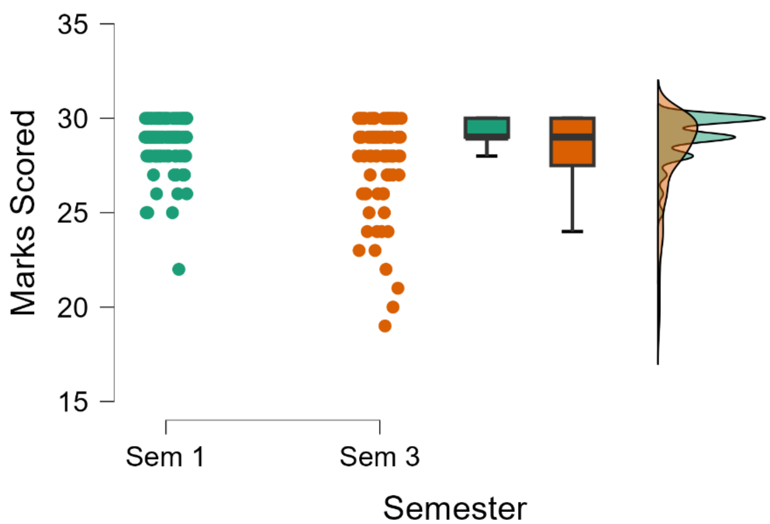

Figure 4: Actual Scores of Sem1 and Semester 3 students in Entangled Worlds: Technology and the *Anthropocene* course

An independent samples t-test was done to see the difference in actual performance scores for Semester 1 and Semester 3 students. The results from Semester 1 (Mean = 29.022, SD = 1.28) and Semester 3 (Mean = 28.021, SD = 2.39) indicate that there is a slight difference in the actual performance scores between two trials and Semester 1 students did better in comparison to the Semester 3 students $t(22) = 3.72$, $p < .001$.

Qualitative Data Analysis from Survey

Student feedback revealed a multifaceted experience with the project-based learning (PBL) approach in the course. While some found it deeply enriching, some felt its potential was not fully realized. The key themes that came from the survey feedback are as follows:

Positive Impacts:

1. Deep Thinking and Critical Reflection: Many students embraced the four-step project structure, appreciating its guidance through a “critical examination” of course themes (as one student put it). Student responses like “allowed me to think deeply about the ethical, social, and environmental dimensions of technology” and “envisioning a future that transcends the limitations of technology” highlight the introspective aspect of the projects.

2. Interdisciplinary Learning and Real-World Application: The PBL approach resonated with those seeking to “apply and integrate knowledge from different disciplines,” which was demonstrated in comments like “authentic and meaningful tasks related to the Tech *Anthropocene* concept.”

3. Engagement and Participation: The regular project submissions fostered active learning. Students reported that their “participation went up” and appreciated the “proper structure” that kept them “working on it regularly.” This sentiment is echoed in statements like “increased my involvement with the course material” and “submissions urged me to interact regardless.”
4. Transformation in Thinking: Several students noted a shift in perspective. One commented, “It made me respect humanities more and know how it’s a lot more than history”, while another highlighted the ethical dimension: "it helped me realize that it's not only about solving problems, it's about how you solve them keeping in mind its possible consequences on our planet."

Challenges and Suggestions for Improvement:

1. Project Depth and Length: While some students valued the conciseness, others yearned for deeper explorations. Quotes like “submission deadlines too short to think deep enough” and “if this module was longer...and we were supposed to go more deeply...it would be very helpful” illustrate this desire for extended engagement.

2. Assessment and Feedback: The in-class submission format limited feedback and real-world engagement opportunities. Students expressed a need for “more structured

feedback mechanisms" and "I wish it had gone beyond in-class submissions to engage with the real world" to enhance their learning.

Interpretation

These results suggest that the PBL approach was generally well-received by students, particularly in terms of promoting understanding and engagement with the course content. While its impact on deeper thinking transformation appeared positive for many, further investigation might be needed to understand the factors influencing individual variations in this area.

Discussion

How are student learning and performance affected when a project-based approach (PBL) is used to teach humanities to engineering students?

Quantitative data analysis through a paired samples t-test shows that students did better when gaining humanities knowledge through a project-based approach (PBL) as the students did significantly better in the Entangled Words: Technology and the *Anthropocene* course which used PBL than in the RTS course taught using a traditional humanities approach. Therefore, PBL was a successful pedagogical tool in increasing the learning and performance of engineering students in learning humanities.

Does previous exposure to humanities taught using conventional pedagogies have any effect on engineering students' perception of humanities courses taught by the PBL approach?

An independent samples t-test reveals that Semester 1 students (who had never taken a humanities course since middle school) had a slightly better perception of the Entangled Worlds: Technology and the *Anthropocene* course when compared to the Semester 3 students. This reveals that although course perception ratings for both the groups were high, students who had already been exposed to a purely humanities approach before like the RTS course had a lower perception of a humanities course when compared to students who did not take any humanities course.

Does previous exposure to humanities taught using conventional pedagogies have any effect on engineering students' actual course performance taught by the PBL approach?

To further investigate the aforementioned result, another independent samples t-test was done for the actual student performance in Entangled Worlds: Technology and the Anthropocene course which revealed that Semester 1 students did slightly better in actual performance as well when compared to Semester 3 students which confirms our hypothesis that previous exposure to humanities courses taught using a traditional approach does affect course perception and performance in other humanities courses for engineering students.

Key Findings

1. Project-based learning (PBL) approach is an effective way to teach humanities to engineering students. Students performed significantly better in a humanities course that used PBL than in a course that used a traditional lecture-based approach.
2. Students who have not had previous exposure to humanities courses for years tend to have a more positive perception of a humanities course taught using PBL than students who have already taken a humanities course through a traditional pedagogical approach.
3. Students who have not had previous exposure to humanities courses also tend to perform slightly better when taught using a PBL approach than students who have already taken a humanities course through a traditional pedagogical approach.

Future Research

We can employ open-ended questions or focus groups to gain a deeper understanding into student experiences and reasons behind their responses. Further, the analysis of data by relevant subgroups to identify potential differences in PBL's effectiveness for different student profiles will give more conclusive results.

Looking forward, these findings suggest several actionable steps to enhance the PBL experience:

1. Extend project timelines or offer optional deeper exploration tracks to cater to students seeking more in-depth engagement.
2. Implement structured feedback mechanisms that provide constructive criticism and guidance throughout the project process.
3. Explore opportunities for real-world application, potentially through partnerships with organizations or guest speakers related to the course themes.

By addressing these challenges and leveraging the identified strengths, the PBL approach can be further optimized to unlock its full potential as a transformative learning experience that promotes not only knowledge acquisition but also critical thinking, interdisciplinary connections, and create a more impactful learning experience for future students.

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