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Patent-Oriented Project-Based Learning in Engineering Design Education: Student Perspectives from an Agricultural Machinery Course

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Abstract
This study investigates the educational value of a patent-oriented project-based learning (PBL) approach implemented within an undergraduate engineering design course. The intervention was embedded in an Agricultural Machinery Design course during the 2024-2025 academic year and involved 12 senior students enrolled in a Biosystems Engineering program. A qualitative-dominant single-case mixed-methods design was adopted, integrating descriptive survey data with qualitative evidence obtained from structured open-ended questionnaires and semi-structured interviews. The results suggest that the patent-oriented PBL activity was perceived as a beneficial learning experience, particularly in fostering creative thinking, innovation awareness, technical communication, and professional responsibility. Students reported gains in the use of technical terminology, understanding of engineering design processes, and appreciation of teamwork. Qualitative findings also revealed recurring challenges in patent writing, especially regarding novelty assessment, technical drawing, and group coordination. Despite these challenges, students emphasized substantial learning gains, including a clearer understanding of the patent system, the distinction between theoretical knowledge and practical application, and the value of collaborative problem-solving. Given the small sample size and single-course context, the findings should be interpreted as context-specific, but they provide practical insights for educators seeking to integrate innovation-oriented and patent-related activities into engineering design courses.

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1. Introduction

Project-based learning (PBL) has gained increasing attention in engineering education as a method for enhancing students' engagement, creativity, and problem-solving abilities (Thomas, 2000; Prince and Felder, 2006). Unlike traditional lecture-based approaches, PBL emphasizes active student participation, hands-on experience, and the real-world application of knowledge. When integrated with authentic challenges such as patent development, PBL can offer students a learning experience that bridges theoretical understanding, engineering design practice, and innovation awareness. Patent-oriented educational tasks may also help students recognize the role of intellectual property systems in transforming technical ideas into professional outputs (Hennessey and Amabile, 2010). Research in recent years has consistently demonstrated the pedagogical value of PBL across various disciplines. Studies emphasize that PBL enhances self-directed learning, collaboration, and creativity—key competencies required for engineering students in a rapidly evolving professional landscape (Larson et al., 2020; Mutanga, 2024). Furthermore, it has been found that students are more motivated and perform better academically when engaged in project work that is meaningful and connected to real-life contexts (Schuman et al., 2022; Ceh-Varela et al., 2023). It is well-documented that academic motivation significantly impacts critical thinking development in university students (Berestova et al., 2022). Academic motivation encompasses both intrinsic and extrinsic influences that drive students to participate in educational activities, demonstrating their level of interest, persistence, and general orientation toward academic responsibilities (Athirathan, 2024). This form of motivation plays an important role not only in achieving academic success but also in enhancing critical thinking abilities, which entail the systematic analysis and evaluation of information to reach well-justified judgments. Studies specifically conducted with agriculture students demonstrated that intrinsic motivation is a strong predictor of satisfaction with professional choice in agriculture programs (Kovalčikienė, 2015). Critical thinking involves the capacity to rigorously evaluate information, question underlying assumptions, and address problems with effective solutions. It is widely recognized as a core competency for both personal and professional development, supporting reflective inquiry, and intellectual engagement. High levels of academic motivation are strongly associated with the development of critical thinking skills, as motivated students are more inclined to participate in complex cognitive tasks. In contrast, low motivation may hinder students' willingness to engage in analytical and problem-solving activities. Creative self-efficacy refers to the belief in one's ability to generate original ideas and solutions. It plays a significant role in shaping both academic motivation and critical thinking. Empirical findings suggest that students with higher creative self-efficacy are more likely to approach academic tasks with enthusiasm and apply critical thinking more effectively. This association emphasizes the value of cultivating students' confidence in their creative potential to enhance both their academic engagement and performance. Within the field of agricultural engineering, PBL has been shown to improve student performance in design-based tasks and promote deeper understanding of complex systems (Castillo-Ruiz et al., 2023; Burmesch et al., 2024). Agricultural machinery education is particularly suitable for project-based and patent-oriented work because it requires students to integrate machine design, tractor use, mechanization planning, safety, ergonomics, and sustainability. Beyond machinery-specific issues, nexus-based studies on agricultural sustainability show that crop production, bioenergy, land use, water, energy, and carbon relationships are interconnected and require systems-oriented problem solving (Degirmencioglu et al., 2019; Ertuğrul et al., 2022; Ertuğrul et al., 2024; Ertuğrul et al., 2026). Recent studies on tractor use, land consolidation, mechanization planning, workplace organization, and agricultural safety in Türkiye also show that agricultural machinery problems require both technical and human-centered solutions (Özgünaltay Ertuğrul and Değirmencioğlu, 2021; Özgünaltay Ertuğrul, 2025a; Alkan and Özgünaltay Ertuğrul, 2025; Özgünaltay Ertuğrul et al., 2025). Similarly, studies on occupational health and safety awareness and ergonomic priorities in agricultural technologies emphasize the need to train future engineers not only in technical design but also in professional responsibility, safe operation, and user-oriented innovation (Özgünaltay Ertuğrul, 2025b; Özgünaltay Ertuğrul et al., 2026). In courses involving agricultural machinery and equipment, hands-on, inquiry-based, and project-oriented instructional approaches may therefore support students' engagement with authentic engineering problems (Zhang et al., 2024; Patahuddin et al., 2023). Team-based learning environments also play a crucial role in shaping students' academic experiences. Research indicates that collaborative learning, especially when implemented with clearly defined roles and responsibilities, helps students become more accountable and engaged (Figland et al., 2020). When students are encouraged to take initiative, communicate their ideas, and contribute to a collective outcome, they are more likely to develop professional competencies aligned with real-world expectations (Mutanga, 2024; Ceh-Varela et al., 2023). These benefits are particularly relevant for agricultural engineering students, who are expected to address complex problems such as machinery design, environmental sustainability, and food security through interdisciplinary thinking and innovation (Larson et al., 2020). The pedagogical value of PBL has also been affirmed in hybrid learning environments, where both face-to-face and online modalities are used. Such settings allow flexibility while maintaining the rigor of hands-on, project-driven education (Ceh-Varela et al., 2023). Additionally, the implementation of frameworks such as CDIO (Conceive-Design-Implement-Operate) has further structured the application of PBL, particularly in design-intensive courses (Wang et al., 2021). Although studies have highlighted the benefits of PBL in various engineering domains, limited research has examined its implementation in agricultural machinery design courses from a patent-oriented perspective. There remains a gap in the literature regarding how such practices influence students' technical growth, collaborative skills, innovation awareness, and professional identity development in agricultural engineering education (Yadav et al., 2011). This study addresses this gap by investigating a patent-based PBL implementation in the "Agricultural Machinery Design" course offered to senior undergraduate students. The pedagogical design aimed to simulate the process of creating a real patentable solution, allowing students to work collaboratively, identify technical problems, develop innovative models, and complete patent application forms. Through this approach, students were expected to strengthen both their technical and soft skills in a structured, yet creative learning environment. The relevance of this approach is also supported by a recent agricultural machinery design example in which a high-pressure seed sowing mechanism capable of sowing from different distances was developed as a master's thesis and associated with a university-based utility model application titled Tohum Ekim Fişeği (Saka, 2025; Saka and Ertuğrul, 2025). Such examples illustrate how agricultural machinery design activities can progress from conceptual design to tangible intellectual property outputs. Drawing upon qualitative data supported by descriptive quantitative data, including open-ended questionnaire responses, semi-structured interviews, creative self-efficacy scores, and academic motivation scores, this study aims to explore students' experiences and perspectives regarding the patent-writing project. The following research questions guide the inquiry:

-What are the students' reflections on the patent-writing experience?

-In what ways did the project contribute to their academic and personal growth?

By examining students' engagement with the patent-based project, this study contributes to the growing body of knowledge on project-based engineering education and offers practice-oriented insights for educators aiming to integrate innovation, intellectual property awareness, and authentic design tasks into agricultural machinery and related engineering curricula.

2. Material and Method

2.1. Research design

This study employed a qualitative-dominant single-case mixed-methods design to explore the implementation of a patent-oriented project-based learning activity within an undergraduate course. The case was bounded by a specific course, student group, institution, and educational intervention. Qualitative data were used as the primary source for understanding students' experiences, while quantitative scale scores were used descriptively to provide supporting contextual information about students' creative self-efficacy and academic motivation.

2.2. Participants

The participants of this study were 12 fourth-year undergraduate students enrolled in the "Agricultural Machinery Design" course at the Department of Biosystems Engineering, Faculty of Agriculture, Kırşehir Ahi Evran University, during the 2024–2025 academic year. All participants volunteered to take part in the study and reported no prior experience with patent-oriented project work. Because the study focused on a single course implementation, the sample was intentionally limited to students who completed the patent-oriented PBL activity.

2.3. Data collection tools

The data were collected using three tools: an open-ended online questionnaire, semi-structured interview questions, and standardized survey scales. The instruments were designed to explore students' experiences in relation to the patent-writing process, collaborative work, technical development, motivation, and perceived challenges. The open-ended questionnaire allowed participants to express their reflections in writing, while the interviews encouraged deeper elaboration on key themes. The survey scales were used to obtain descriptive baseline information about students' academic motivation and creative self-efficacy.

Academic motivation scale (AMS)

The AMS developed by Vallerand et al. (1992, 1993) is based on Self-Determination Theory and aims to determine the sources and levels of students' academic motivation. The scale consists of 28 items and seven subscales. Items are rated on a seven-point scale ranging from 1 ("does not correspond at all") to 7 ("corresponds exactly"). Higher subscale scores reflect stronger endorsement of the corresponding motivation dimension. The scale was adapted into Turkish by Karaguven (2012), and the reported Cronbach's alpha coefficients ranged between .62 and 86.

Creative self-efficacy scale (CSES)

The CSES is an eight-item, unidimensional scale developed by Carmeli and Schaubroeck (2007) to assess individuals' subjective belief in their capacity to be creative in the workplace. Responses are rated on a six-point Likert-type scale ranging from 1 ("strongly disagree") to 6 ("strongly agree"). The Turkish adaptation of the scale was conducted by Alayoğlu (2019), yielding a Cronbach's alpha coefficient of 93.

2.4. Patent-Oriented PBL implementation

The patent-oriented PBL activity was embedded in the regular structure of the Agricultural Machinery Design course. Students worked collaboratively to identify an agricultural machinery-related technical problem, discuss the novelty and applicability of possible solutions, develop a conceptual model aligned with course content, prepare technical drawings where necessary, and draft the main components of a patent application such as the title, technical field, background, novelty statement, description, and claims. Instructor guidance focused on technical feasibility, clarity of expression, design-process logic, and alignment between the proposed solution and the patent-writing format. Where appropriate, students were encouraged to consult institutional resources such as the Technology Transfer Office for procedural guidance. The activity was not limited to producing a final written document;

it was designed to help students experience the relationship between engineering design, innovation, intellectual property, teamwork, and professional responsibility.

2.5. Researcher role

The researcher also served as the course instructor and therefore had a dual role in both designing and facilitating the educational activity. To minimize potential bias, data collection was conducted after the course activity and final assessments had been completed, and student responses were anonymized before analysis. During the course, the researcher provided guidance on patent writing and technical aspects but refrained from influencing students' reflections or responses.

2.6. Data collection procedure

Data were gathered following the completion of the course activity and final assessments to ensure that students had full exposure to the patent-writing process and that participation would not affect course grades. Before data collection, students were informed about the purpose of the study, voluntary participation, confidentiality procedures, and the fact that their responses would be used only for research purposes. Interviews were conducted face-to-face and lasted approximately 15–20 minutes. The online questionnaire was administered through a secure platform, and responses were collected from all 12 students.

2.7. Data analysis

Thematic content analysis was applied to analyze the qualitative data. Student responses were first read repeatedly to identify meaningful units. These units were then coded and grouped under recurring themes such as innovation awareness, technical learning, collaboration, professional development, and challenges. Interview and questionnaire responses were compared for consistency and depth, and direct quotations were included to support the interpretation of findings. Quantitative survey data were analyzed descriptively by calculating means and standard deviations. The Academic Motivation Scale and Creative Self-Efficacy Scale scores were used to provide contextual information about students' motivation and creative self-efficacy levels. Because of the small sample size (N = 12), inferential findings were interpreted cautiously and only as exploratory indicators rather than as evidence of generalizable effects.

2.8. Credibility and ethics

Ethical principles were strictly followed throughout the research process. Ethical approval for the study was obtained from the Kırşehir Ahi Evran University Scientific Research and Publication Ethics Committee of the Faculty of Science and Engineering with the decision number 2025/04/04. In addition, written institutional permission was received from the Dean's Office of the Faculty of Agriculture before data collection. All participants were informed about the purpose and scope of the study, their voluntary participation rights, confidentiality procedures, anonymity of responses, and their right to withdraw from the study. Informed consent was obtained from all participants. The identities of the participants were kept confidential, and the data were anonymized during analysis. Participation in the research had no effect on students' course grades or academic evaluation. To enhance the trustworthiness of the qualitative findings, questionnaire and interview data were compared for consistency. Direct quotations were included to support the interpretation of student reflections. In addition, coding and theme development were cross-validated by a second academic with expertise in qualitative research. Disagreements in coding were discussed until consensus was reached.

3. Results and Discussion

This section presents the findings obtained from both qualitative and quantitative data, and discusses them based on the relevant literature.

3.1. Findings from the qualitative data

The interviews and open-ended questionnaire responses reflected the perspectives of twelve undergraduate students enrolled in the Agricultural Machinery Design course at the Department of Biosystems Engineering, Faculty of Agriculture, Kırşehir Ahi Evran University. The analysis produced four main themes: (i) innovation and patent awareness, (ii) technical and professional growth, (iii) teamwork and role distribution, and (iv) challenges in patent writing and technical visualization. Students' reflections indicated that the patent-based activity helped them connect theoretical engineering design knowledge with practical innovation processes. In particular, students emphasized learning how a real patent application is structured, how novelty should be considered, and why technical descriptions and drawings must be precise. Their responses also suggested that collaboration and role sharing were central to the success of the project, although group coordination sometimes created difficulties (Table 1).

Table 1. Students' reflections on patent-based project practice

Student Comments
It was a very valuable experience. It was like a priceless opportunity for a student.
We learned how to prepare application forms for patents and what is required in a real patent.
I developed myself and learned how the patent process works.
It contributed a lot to our teamwork and innovative thinking.
We created a useful model aligned with the course content. It was a fun group project.
I believe such applications should be used in other courses as well.

Students reported that the patent-based project contributed to their understanding of innovation, problem-solving, and creative thinking. Several students emphasized the value of working as a team and learning about the official patent application process. One participant stated, "The project gave us practical insight into how a real patent process is initiated and evaluated." Another noted, "This experience made me feel like an actual engineer solving real-world problems." These statements show that the activity supported not only technical learning but also students' sense of professional identity (Table 2).

Table 2. Students' suggestions for future participants

Suggestions
Choose your teammates carefully and be sure that roles are equally shared.
If possible, take support from the Technology Transfer Office during the writing process.
Having your own patented product can be a great motivator—definitely recommended.
More project-based learning like this should be included in other technical courses.

In terms of future recommendations, students emphasized the importance of team selection, role clarity, equal task distribution, and external support. The Technology Transfer Office (TTO) was highlighted as a potentially useful resource for patent preparation and submission guidance. These suggestions indicate that patent-oriented PBL requires both pedagogical structure and procedural support. Overall, the qualitative findings suggest that integrating patent-oriented PBL into engineering curricula can support technical competencies, innovation awareness, confidence, and motivation through real-world application. However, these findings should be interpreted within the context of a small, single-course case study. In order to visualize the core themes that emerged from student reflections, a word cloud was generated based on open-ended responses collected through interviews and questionnaires. This visualization highlights frequently mentioned terms such as learning, application, innovation, problem-solving, and teamwork. The word cloud was used only as a supplementary visual aid; the interpretation of qualitative findings was based primarily on thematic content analysis and representative quotations (Figure 1).

Figure 1. Word cloud representing core themes in students' reflections on the patent-based project experience

3.2. Findings from the quantitative data

The means and standard deviations for creative self-efficacy, academic motivation, and the academic motivation subscale scores are given in Table 3. Descriptive analyses indicated that students reported relatively high levels of creative self-efficacy (M=44.20, SD=5.01) and academic motivation (M=132.00, SD=25.70). The subscale scores of the Academic Motivation Scale generally showed moderate-to-high endorsement of intrinsic and extrinsic motivation dimensions, while amotivation was comparatively lower. The relatively low AMOT score indicates limited amotivation compared with the intrinsic and extrinsic motivation dimensions (Table 3).

Table 3. Means and standard deviations for variables

	Mean	**SD**
Creative self-efficacy	44.20	5.01
Academic motivation	132.00	25.70
IMTK	21.30	5.02
IMTA	21.10	4.14
IMES	19.30	5.74
EMER	19.80	4.20
EMIN	17.90	5.90
EMID	21.10	3.78
AMOT	11.50	4.75

IMTK: Intrinsic Motivation to Know; IMTA: Intrinsic Motivation to Accomplish; IMES: Intrinsic Motivation to Experience Stimulation; EMER: Extrinsic Motivation External Regulation; EMIN: Extrinsic Motivation Introjected Regulation; EMID: Extrinsic Motivation Identified Regulation; AMOT: Amotivation.

A Mann-Whitney U test was conducted as an exploratory analysis to compare participants with prior project experience and those without. The results are given in Table 4. Significant differences were observed in intrinsic motivation to accomplish (IMTA) (U=5.00, p=.048) and intrinsic motivation to experience stimulation (IMES) (U=3.00, p=.022). Students who had not previously engaged in project work reported higher levels of accomplishment-related intrinsic motivation (M=22.90) and stimulation-related intrinsic motivation (M=22.30) compared with their peers who had prior project experience (M=18.60 and M=15.20, respectively). Given the small sample size, these findings should be interpreted as exploratory and context-specific (Table 4).

Table 4. Mann-Whitney U test between the participants who have previously worked on a project and those who have not

	Mann-Whitney U	p	Hodges-Lehmann estimate
Creative self-efficacy	17.50	1.000	0.00
IMTK	10.00	0.235	1.00
IMTA	**5.00**	**0.048***	**2.00**
IMES	**3.00**	**0.022***	**5.00**
EMID	10.50	0.272	3.00
EMIN	12.00	0.414	3.00
EMER	13.50	0.565	-2.00
AMOT	10.00	0.238	-3.00

The overall results suggest that students participating in the PBL activity generally reported high levels of creative self-efficacy and academic motivation, consistent with previous research emphasizing that PBL can support students' confidence in their creative abilities (Hennessey & Amabile, 2010; Larson et al., 2020). However, prior project experience was associated with lower intrinsic motivation to accomplish and to experience stimulation in this course. This pattern may reflect reduced novelty or challenge for previously experienced students. The absence of group differences in creative self-efficacy and extrinsic regulation suggests that confidence in one's creative capacity and externally driven motives were relatively stable regardless of prior project experience. The comparatively low amotivation score indicates that most students were engaged with the course activity. Limitations: The small sample size (N=12), the single-institution design, the absence of a pre-test/post-test comparison, and reliance on self-reported student perceptions limit the generalizability of the findings. Future research with larger samples, comparison groups, and longitudinal designs could examine whether tailoring project complexity by experience level prevents possible declines in intrinsic motivation among students who have prior project experience.

4. Conclusions and Recommendations

The findings of this study indicate that patent-oriented PBL can provide a meaningful context for connecting engineering design education with innovation awareness, professional responsibility, and collaborative problem-solving. Students' reflections suggest that the activity supported their understanding of patent processes, technical terminology, teamwork, and the practical application of theoretical knowledge. These findings are consistent with the conclusions of de la Torre-Neches et al. (2020), who emphasized the role of cooperation and evaluation in PBL dynamics, and with Börekci and Uyangör (2019), who demonstrated that PBL activities can positively influence metacognitive awareness and self-regulation strategies. Moreover, the interconnection between student characteristics and academic performance, as explored by Sáenz-Castro et al. (2021), suggests that intentional educational practices should be tailored to student diversity to maximize learning outcomes. This aligns with Scarbrough et al. (2004) emphasis on learning-by-reflection as a critical dimension of PBL that enhances personal and organizational knowledge transformation. In the present study, patent-oriented tasks appeared to provide students with opportunities for reflection, technical expression, and real-world design thinking; however, these conclusions should be treated as context-specific because of the limited sample size.

Therefore, it is recommended that educational institutions **integrate project-based methods** that:

- Promote **intrinsic motivation** through meaningful, real-world tasks,
- Strengthen students' **critical thinking abilities** via collaborative problem-solving,
- Enhance **creative self-efficacy** through open-ended exploration and ownership of learning,
- And develop **metacognitive and self-regulatory strategies** through structured reflection and feedback cycles.

These approaches may result in deeper learning experiences, higher engagement, and better preparation for complex, interdisciplinary challenges in both academic and professional contexts. Future implementations should include clearer rubrics for patent-writing components, structured support for technical drawings and novelty assessment, and stronger collaboration with Technology Transfer Offices.

Declaration of Author Contributions

G.Ö.E. conceived and designed the study, implemented the patent-oriented project-based learning activity, introduced the patent process to the students, collected the qualitative and quantitative data, and prepared the initial draft of the manuscript. P.Ö.P. conducted the statistical analyses of the Academic Motivation Scale and Creative Self-Efficacy Scale data and contributed to the interpretation of the quantitative findings. Both authors jointly interpreted the results, contributed to the discussion and conclusion sections, critically revised the manuscript, and approved the final version for publication.

Declaration of Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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Ethics Committee Approval

The ethics committee approval for this study was obtained from the Kırşehir Ahi Evran University Scientific Research and Publication Ethics Committee of the Faculty of Science and Engineering with the decision number 2025/04/04. In addition, written permission was received from the Dean's Office of the Faculty of Agriculture prior to data collection. All participants were informed about the purpose of the study, their voluntary participation rights, confidentiality procedures, and the fact that participation would not affect their course grades.

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