

PAPER

Action Research for the Improvement of a Project-Based Learning Approach in Design Studies

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ABSTRACT

This study aims to identify opportunities for improving a project-based, design-oriented learning approach in design studies, focusing on mechanisms that promote student motivation, competence, and identity development in the context of interdisciplinary cooperation. The following research methods were employed: scientific literature analysis and focus group discussions to ensure data triangulation. Action pilot research was conducted during the development of a design project, with its stages aligned to the phases of the design process. The findings highlight key factors contributing to students' personal development and successful project outcomes. These include the organization and material infrastructure of the study process, the importance of collaboration across institutional units, among lecturers, and between lecturers and students. The study concludes that strengthening collaboration and stakeholder involvement in the improvement of the study process enhances students' learning experiences, facilitates knowledge exchange, and increases motivation and learning effectiveness.

KEYWORDS

action research, project-based learning, design-based learning, focus group discussion

1 INTRODUCTION

The challenges of the 21st century, which contribute to the rapid development of diverse industrial digital solutions, make it necessary to change the understanding and approach in the study process. The prospects for the development of higher education in the field of design technologies are related to an important aspect, namely, supporting independent research activities of students. The relevance and availability of innovations, advanced materials, and technologies transform/create changes in the study of design technologies directly from the research aspect. They influence the development of design technology as an integrated interdisciplinary industry, for the creation of new products/services [1].

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The research intervention focuses on a critically identified problem: the adaptation of design students of the first year of study during the transition period from high school to graduate school.

This transition poses significant academic and social challenges, as students face radical changes in the degree of independence and difficulty of studying. Research in technical colleges indicates that relationships with lecturers and knowledge of learners are especially important for students, which is an essential factor for successful adaptation [2]. Empirical data show that in the first year of studies there is a marked tendency to decrease motivation, which is directly related to the inability to see the relevance between general study courses and the development of one's professional skills. In addition, a unique challenge for design education is the specifics of the study culture, in which the student faces constant criticism [3].

The development of study projects in design and technology studies is part of the study process. Often, its organization is limited to the independent activity of the student and the advice of the faculty at the initiative of the student. However, when starting their studies at a university, students have a different experience of self-directed learning. In the first year of study, students sometimes lose motivation to study because it is necessary to take several general study courses that the student does not associate with the development of their professional skills. Therefore, to fully involve first-year students in the process of exhibiting innovative design products from researching user needs to producing a high-precision prototype, the Rezekne Academy of Technology (RTA) (since April 1, 2025, Riga Technical University Rezekne Academy) science grant project "Experimental research on technology synergies in the development of prototypes of bionic design products" was developed. This grant project provides support in the development of the study project, providing an opportunity for academic staff from several disciplines, in cooperation with students and entrepreneurs, to conduct experimental research, to try out laser processing and 3D printing possibilities of various materials, and to develop new, innovative design solutions and product designs using the technologies available at the university. Cooperation between education, science, and business promotes interdisciplinary research in the study process and innovative solutions for the development of prototypes of design products.

The aim of the study is to identify opportunities for the improvement of a project-oriented, design-based learning approach in design studies, focusing on mechanisms that promote student motivation, competence, and identity development in the context of interdisciplinary cooperation.

A project-based learning approach focuses on adapting learning content to practice innovation development by teaching students to solve design problems through study projects in engineering education [4], [5], [6], [7]. This approach, already in the first year of studies, allows the student to engage in a guided design process, which develops the professional and general knowledge and skills of students for future creative projects. The ability to see problems and find solutions to them is an essential characteristic of a professional.

2 THEORETICAL FRAMEWORK

The theoretical basis of the project-based learning (PBL) approach is considered to be constructivist learning theory [8], pragmatic educational theory [9], and discovery learning theory [10]. PBL is essentially "learning by doing," in which students acquire knowledge while developing a design project. Looking back at history, the American psychologist and educational theorist John Dewey emphasized in his theory developed in 1859 that in learning, a person should learn by doing,

learn from experience, learn by engaging the mind, learn by building their own repository of knowledge and creative abilities, and learn by engaging in activities, i.e., learn by cooperation [11]. The learning-by-doing approach gives students meaningful learning since they are actively involved in every step of the educational process, unlike learning theory in the classroom, which can quickly bore students and lead them to forget the material they have studied [12].

Modern research in design and engineering studies emphasizes the relevance of design-based, problem-based, and project-based study approaches. All of these approaches are united by student-centered, interactive learning that challenges students to learn by engaging in the search for solutions to real-life problems.

When developing projects in the study process, students engage in an extended cognitive process in response to a complex question, problem, or challenge. The educator, together with the students, plans, facilitates, and evaluates collaborative projects that ensure student autonomy and decision-making to help students master the appropriate academic content. Twenty-first-century skills such as collaboration, communication, problem-solving, critical thinking, and creating authentic products are meaningful and effective features of project-based learning [13].

Given the interdisciplinarity of the study project in design and engineering studies, the move towards the development of an innovative design project and/or product, and, consequently, its compliance with the design thinking model, it is logical to link the project-based learning approach with design-based learning.

Design-based learning (DBL) is an approach to education that uses design principles and practices as a central element to foster creativity and innovation skills. It is recognized as an appropriate active learning approach to develop value-based solutions that respond to social and technological challenges [14], [15].

Gómez Puente [15], in his empirical literature review of DBL or similar projects in higher engineering education, identifies five essential dimensions for the organization of DBL properties in higher engineering education. These are the project approach, elements of engineering design, the role of the lecturer, evaluation methods, and social context. These five dimensions are essential elements in developing a DBL learning environment in which students work to gain knowledge and understanding by solving problems and developing design projects.

Project-based learning (PBL) was chosen as a direct response to the motivation gap because it offers a student-centered, interactive environment that challenges students to solve authentic problems. The specific intervention within the framework of the RTA grant project activates these mechanisms by actualizing the following: (1) active experimentation: using laser processing and 3D printing technologies for high-precision prototype development; (2) interdisciplinary collaboration: creating an industrially enriched environment that improves students' readiness for the labor market.

The theory of self-determination (SDT) offers a framework for explaining how PBL overcomes loss of motivation by satisfying three basic needs: autonomy, competence, and connection [16]. Using the PBL system in virtual environments (e.g., the Metaverse) combined with design thinking allows students to learn new corpuses of knowledge more efficiently, improve problem-solving techniques, and perform tasks more efficiently [17].

Literature reviews confirm that project-based and challenge-based approaches (CBL) have a positive impact on students' internal motivation when ensuring autonomy in project selection and linking them to professional identity [18]. PBL activates intrinsic motivation as students' "voice and choice" promotes self-directed learning.

The literature research carried out indicates the common features of the project-based and design-oriented learning approach, which is a student-centered, problem-oriented, collaborative study process. This confirms the recognition of Ai et al. [19] that DBL

not only refers to student learning through research and design in project development but also includes the entire learning system and learning process design. Thus, in order to determine the possibilities for improvement of design studies, qualitative research data will be structured according to the concepts of organization of the study process, cooperation in the study process, and personality characteristics of students.

3 MATERIALS AND METHODS

The study was conducted to find out the answer to the research question: In what way does action research structured according to the course of the design process help students achieve the goals of personal development (motivation, identity) and study project development (competence, skills)? In student-oriented research, two directions of research crystallize in modern pedagogy: the learning experience of students, as well as the social experience of students, are studied. The student-centered approach corresponds to the essence of humanistic pedagogy, social constructivism, and the action approach in the study process.

Action research includes a spiral of action and study cycle [20], [21]. Revelation grows as it moves from the implementation of the initial cycle to the planning of the next cycle, which is adjusted, and the research process is repeated. Each stage of the spiral usually includes four distinct phases: planning, action, observation, and reflection. This means that researchers collect data while trying to influence change; that is, they study action as it occurs.

Action research (AR) in this study is not just a methodological choice; it serves as a theoretical framework for the continuous improvement of the DBL approach. The AR cycle (problem identification, development/implementation of an action plan, data analysis, and reflection) is naturally aligned with the iterative nature of design thinking.

The AR ensures that the organization of the study process, which was one of the categories of research data, is continuously optimized. Reflection is used as a tool to recognize problems in course design and develop solutions that are adaptive and responsive to student conditions. This reflexively iterative model is essential to ensure that the DBL/POL approach remains effective in responding to students' changing needs and challenges.

During the development of the study project, action research was conducted, the stages of which correspond to the progression of the design process. It corresponds to the design of qualitative research with an applied orientation, in which the researcher and the subjects collaborate to identify problems and find a solution to them. Both parties are actively involved in the research process, which yields a concrete, practical result related to the study project's goal and provides conditions for a continuous process. Action research was conducted in two phases between February 2024 and June 2024. The first stage included parts of the design process: research, defining problems, and developing ideas.

At the second stage, the parts of the design process were included: prototyping, development, and implementation.

According to a project-based approach, the acquisition, cooperation, reflection, and assessment of knowledge and skills took place within the framework of study courses and extracurricular activities.

To determine the progress of the design project process and the necessary adjustments within the framework of the reflection phase of each stage, a discussion was carried out between both the group of students and the group of lecturers involved to determine the suitability of the content offered in the study courses and the methods

used to achieve the goals of the study project. In total, there were two student group interviews and two lecturer group interviews.

The group interviews took place in person, on the premises of the university. The duration of each group's discussion was about 60 minutes.

The study was conducted in compliance with the ethical principles of academic research. All participants gave their informed consent, were informed of the limited confidentiality due to the format of the group discussion, and were informed of their right to withdraw at any time. The data was anonymized and stored in a secure environment.

Data processing (analysis) of focus group interviews was carried out in a group of two researchers. In parallel with the audio recording, structured observation sheets were used, where information about the activity of the participants and the reactions and interpretations of the researcher, according to the set criteria, was recorded. Qualitative coding included (a) open coding—significant phrases, ideas, and actions were highlighted; (b) axial coding—codes were combined into categories; and (c) Selective coding—central concepts were put forward, e.g., organization of the study process. The reliability of the encoders was ensured by independent coding, comparison, discussion, and joint final coding.

3.1 Participants

The focus group discussion was attended by students of the first year of studies of one academic group, who have received equivalent theoretical and practical training in study classes. Such a choice helps to reveal students' different experiences of forming independent professional activity, which are based on individual personality traits and previous experience in research and innovation.

The discussion of the lecturer group was attended by lecturers, whose study courses acquired the theoretical and practical skills necessary for the development of the study project, as well as lecturer-engineers who helped to implement students' ideas in research centers—materials technology laboratories.

The research base consists of 11 students of the bachelor's study program "Design Technologies" of the first year of studies—nine women and two men. The age of respondents is from 18 to 24 years, as well as six lecturers (five women and one male) who teach study courses or lead the development of study projects, and two lecturers working in materials technology laboratories—two men. The age of lecturers is from 30 to 58 years.

3.2 Design of model

Action research is an iterative process aimed at improving educational practice by combining action with assessment and reflection. This methodology provides a continuous reflexive cycle in which the improvement of the study process becomes part of the learning experience. The use of a performance study guarantees participation and cooperation, involving lecturers, students and other professionals in improving practice. Thus, the study is not only about data collection, but about the design of the learning environment itself, which allows you to continuously assess whether the intervention solves the identified problem.

The development of a study project traditionally provides for independent activity of the student with some consultations with the lecturer-manager. In a project-based and design-oriented study process, the development of a study project is integrated

into the study process, in parallel with the acquisition of related study courses (see Figure 1). This means that by mastering the theory, students link their problem to be solved with clues to the study of the design process. In this way, several lecturers are involved in the process, who, in cooperation with students and among themselves, give instructions, feedback and assessment and guide the study process, as well as are present for the student’s independent activity. So, for example, in the first stage of activity research, students were given the task of developing a design product—a light fixture. Each student chose one of the sources of inspiration—bionics, architecture, or ethnography. Students appropriately set the goal of the study, methods, conducted market research, user surveys, studied analogues, developed sketches, engineering drawings, and determined the most suitable materials and material processing technologies. In the study courses, students were introduced to the methodology for conducting research, methods of sketching, and standards of engineering graphics. The student’s performance—oral presentation, report, and collection of sketches, drawings—was part of the assessment of the appropriate study course. The first cycle of action research was concluded by a student scientific conference, where students presented their research and the idea of the design product to be developed, and answered questions. After this student presentation, the group discussion analyzed the potential of the necessary design research knowledge and skills, the progress of project work, its shortcomings, and the necessary improvements.

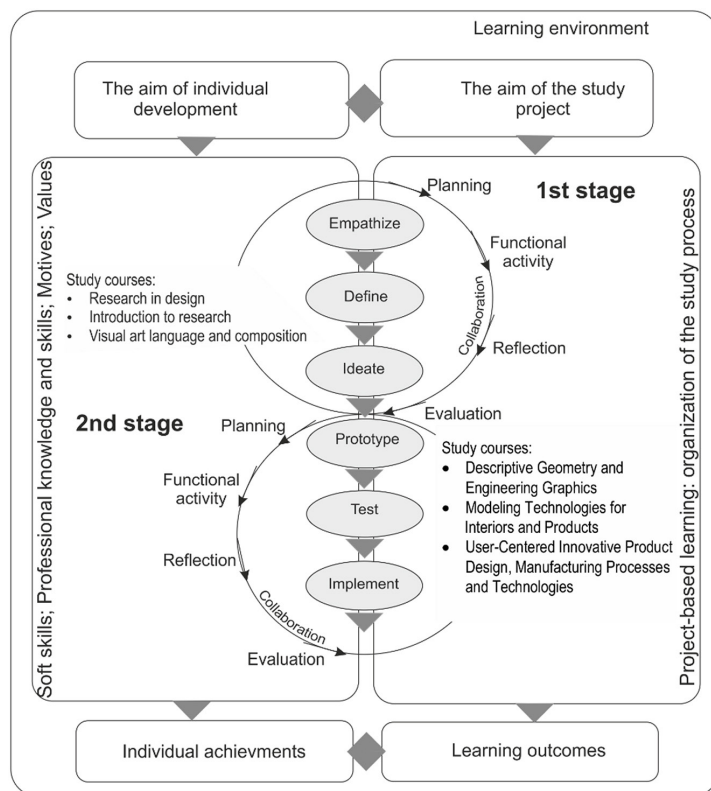


Fig. 1. Structure of the project-based design learning

In the second phase of the action research, students planned the development of the prototype, its testing, development in material, and implementation. First-year students had the opportunity to work in RTA research centers. Students, in cooperation with lecturers of study courses and engineers of research centers, carried out experimental activities. At this stage, low-precision prototypes were developed—mock-ups

and models—followed by the development of high-precision prototypes—design samples. Photofixations of the design process were reflected in the presentations. The developed products—light fixtures—were presented at the exhibition, both in the premises of RTA and in the exhibition of works of design schools and universities of the state “Design Arena” in Riga.

Benefit for student—PBL allows you to gain knowledge on your own and be active in learning skills in the process of “learning by doing.” Using this approach, they can not only acquire knowledge but also show their practical skills, as well as the skills to express an opinion and present their idea, which in general corresponds to the essence of a student-centered approach—to develop students’ individual achievements, learning experience, and social experience.

4 RESULTS

Discussions of focus groups of students and lecturers were recorded in audio format; their transcription was performed, as well as the identification of categories according to the selected concepts. For the concept of ‘Organization of the study process,’ the categories ‘Material and technical base,’ ‘Related study courses,’ and ‘Time planning and organization’ have been selected. The concept of ‘Cooperation’ is characterized by the categories ‘Support in project initiation and progress,’ ‘Consultation and feedback,’ ‘Support of group members,’ and ‘Additional support in specific areas.’ The concept of ‘knowledge and skills in the implementation of the design process,’ design competence, corresponds to the categories ‘development of creativity and innovation,’ ‘technical skills and use of technology,’ and ‘application of theoretical knowledge.’ The term ‘personality traits’ is defined by the category ‘presentation and communication skills’ (refer to Table 1).

The results of the discussions indicate the various, sometimes even diametrically opposite, views of students on the issues of organizing the development of a study project. This confirms the influence of students’ individual traits: motivation, personality traits, previous experience, and learning styles (refer to Table 1). A student-centered study process also requires an adapted approach on the part of lecturers to ensure optimal use of learning opportunities and achievement of learning outcomes. Each student processes and learns information differently, so it is important to provide diverse support.

Table 1. Content units, categories, and concepts identified in a student group discussion

Content Units	Category	Concept
<i>“... It was very good that the use of various resources and materials was ensured, RTA research centers were available...”</i>	Material and technical base	Organization of the study process
<i>“... It was good that some of the courses dealt with project development issues...”</i> <i>“... It was difficult because there were courses not related to the study project in parallel, in which tasks also had to be completed...”; “... Many things and theories were ambiguous because the technology had not been learned beforehand, specific recommendations were needed...”</i>	Related study courses	
<i>“... On the part of the lecturers, stricter time planning would be required, there was little time for product development...”; “... I wanted more support for the division and sequencing of the stages of work...”</i>	Time planning and organization	

(Continued)

Table 1. Content units, categories, and concepts identified in a student group discussion (Continued)

Content Units	Category	Concept
<p>“... The lecturers provided very useful support in helping to define the initial goals...”; “... The lecturers suggested methods that made it possible to choose the most suitable solution for the development of the project...”</p> <p>“... The support was enough to get the project off to a successful start...”</p>	Support for project start-up and progress	Cooperation
<p>“... Lecturers often provided individual advice, which was very valuable...”; “... Feedback helped improve both the research and product design...”; “... The support was sufficient, but in some cases it was desirable to receive advice on technical issues more often...”</p>	Consultation and feedback	
<p>“... We communicated on our own about the possibilities of using technology, the times, we went to consultations together...”</p>	Group member support	
<p>“... I consulted with an industry professional in light design outside of graduate school to develop the best solution...”</p>	Additional support in specific areas	
<p>“... I draw inspiration from researching analogues on internet sites...”; “... The beginning of my idea was the wave motif that I developed in sketches...”; “... Creativity was driven by working with material: experimenting with materials to achieve the chosen form...”</p>	Developing creativity and innovation	Knowledge and skills in the implementation of the design process Design literacy/competence
<p>“... It was necessary to use drawing computer programs...”; “... We got to know the technology in cooperation with engineers...”; “... Previously, there was no skill to operate with laser technology...”; “... I learned how to prepare digital material to print a 3D model...”</p>	Technical skills and use of technology	
<p>“... It was necessary to study topics that had not been studied before, it complicated understanding...”; “... Research in databases is very specific, bionics is found more in medical articles than in relation to product design...”</p>	Application of theoretical knowledge	
<p>“... I would like to learn how to better present the developed design...”; “... I don't want to speak, I think there are students who can speak and communicate freely and there are those who find it difficult...”; “... It is possible that by doing this more often, skills can be developed...”; “... Innate shyness interferes with free communication...”</p>	Presentation and communication skills	Personality traits

The categories that characterize the concepts differ in the discussion of lecturers’ focus groups compared to the student discussion. Categories determine students’ activities and skills in the process of developing a study project from the point of view of lecturers (refer to Table 2).

Table 2. Content units, categories and concepts identified in the discussion of the lecturer group

Content Units	Category	Concept
<p>“... Initially, students have no idea of the work intensity of the task and the time required to complete the tasks...”; “... Some students are passive at first, do not always complete the assigned tasks on time...”; “... The most active students are able to plan their meetings and work well, both with lecturers and with workshop engineers, are able to prepare the necessary materials in a timely manner...”</p>	Self-organization and time management	Organization of the study process

(Continued)

Table 2. Content units, categories and concepts identified in the discussion of the lecturer group (Continued)

Content Units	Category	Concept
<i>"... There are different students. There are students who are actively involved in discussions and ask questions when they are unsure..."; "... If a student is not afraid to seek help, both from lecturers and workshop engineers, this indicates his ability to cooperate and seek support to improve his work..."</i>	Active involvement and initiative of students	Cooperation
<i>"... Students of the 1st year of study have little experience in clearly and accurately formulating their ideas, questions and needs..."; "... In the process of communication, the student expects approval or adjustments to his or her plan..."; "... There are students who are able to express in an understandable and concrete way what they need from lecturers and workshop engineers, as well as to see problems that may arise during the project..."</i>	Clarity and accuracy of communication	
<i>"... Students gained their first experience using workshop equipment. The technical solutions and instructions on materials chosen by the workshop engineers were decisive..."; "... The students' task was to understand and use the engineers' recommendations, as well as to contact them about technical problems to find the most suitable solutions for their design idea..."</i>	Under-standing technical problems	
<i>"... Students of the 1st academic year had to accept the challenge of acquiring many knowledge and skills independently, taking responsibility for their work, while adapting to new challenges or changes..."; "... Flexible thinking and the ability to adapt to different situations are important in the design process..."; "... Students who are ready to solve problems and understand the need to adapt to different circumstances get a better experience and a result of work..."</i>	Ability to take responsibility and adapt	
<i>"... In the study course "Research in Design" indications are given about research methods. Students carry out market research and user needs research within the framework of their project. The main task and challenge are to compile a questionnaire with meaningful questions..."; "... If the student is able to understand the essence of the study, which is consistent with the goals of his research, this indicates an understanding of the processes of design research. Such skills are essential for conducting sound research..."</i>	Selection of research methods	Knowledge and skills in the implementation of the design process Design literacy/competence
<i>"... A well-designed study indicates the ability to identify the main problems and their context, as well as to find appropriate theoretical sources and practical solutions..."; "... If students are able to conduct a thorough review of the literature and analyze existing research, this demonstrates their understanding of the basic principles and methodology of design..."; "... Practice shows that students have problems with the analysis and interpretation of information sources, according to the topic of the study project..."</i>	Depth of research and analytical skills	
<i>"... More attention needs to be paid to students' skills to develop innovative solutions..."; "... It is a task for lecturers, to use a variety of methods of generating ideas in different study courses. Students use more analogues found on the Internet..."; "... It is difficult for many students to distance themselves from what they see and to develop diverse sketches without the initiative of the lecturer..."; "... Creativity is sometimes undermined by ignorance of the possibilities and costs of producing an idea..."; "... There are students who are able to think outside the usual frames and adapt to the challenges of modern design, are able to create new, innovative ideas that are different from traditional solutions..."; "... You have to ask yourself the question – how to encourage students' ability to create diverse ideas and evaluate them..."; "... If a student offers different solutions to the same problem and is able to evaluate the advantages and disadvantages of each of them, this indicates a deeper understanding of the design problem..."</i>	Creativity and innovation Diversity and brainstorming	
<i>"... Students had the opportunity to choose different materials for making mockups and evaluate the necessary properties of the material of the final product. The students analyzed their work, including the results of the experiments and the solutions chosen..."; "... Students who see potential problems, limitations and potential improvements, and take appropriate actions, show good end results..."; "... Some students don't want to make changes to the idea that has been started..."</i>	Iterative approach and evaluation	
<i>"... It is good if students are able to assess their strengths and areas that still need to be improved, it is a sign of their ability to learn from experience and develop in the future..."; "... Often students do not want to improve the results of their work, which indicates a lack of critical thinking..."</i>	Critical thinking and analysis	
<i>"... The students used computer programs to prepare the drawings necessary for the use of laser technology and 3D printing..."; "... A lot of corrections had to be made by engineers so that the prepared files could be used. 1st year students have little understanding of technology. The result was not always satisfactory..."; "... It's basically in line with the problems of design development..."</i>	Use of technology	

(Continued)

Table 2. Content units, categories and concepts identified in the discussion of the lecturer group (*Continued*)

Content Units	Category	Concept
<p>“... The conference showed how clearly, structured and persuasive students are able to present their research. Some of the presentations didn’t impress me. We need to show examples, because the presentation also has a design that shows the student’s competencies to effectively use various technologies, tools and graphic design...”; “... Good visualizations can greatly improve the understanding of the study and have a greater impact on the audience...”; “... A student’s speaking skills in front of an audience should be developed by allowing students to present the tasks completed in different study courses...”; “... Unfortunately, there were some students who were “scared” and did not come to the conference. This is more indicative of irresponsibility...”; “... Each student understands and learns information differently, so it is important to provide a variety of support...”; “... In general, the students successfully and most importantly – carried out the research part of the study project and the development of the product in a timely manner, for which the lecturers and engineers involved should also be thanked...”</p>	Presentation skill and communication	Personality traits

5 DISCUSSION

This study was conducted as an action research process aimed at improving a PBL approach in first-year design studies. The practical problem that initiated the research was students’ difficulty in managing an open-ended design project due to limited prior experience in self-directed learning, project planning, and systematic engagement with the design process. Similar challenges for novice learners in project-based and design-based learning environments have been reported in previous research, emphasizing the need for appropriate scaffolding in early study stages [22], [23], [24].

Practical problem and relevance to existing research. Project-based learning is widely recognized as a suitable pedagogical approach for design and engineering education, as it enables students to acquire multidisciplinary skills through authentic project work [22]. Davis and Dubberly [25] argue that design education should integrate theoretical knowledge with iterative practice, allowing students to experience real-world complexity. However, research also indicates that first-year students often struggle with the ambiguity and autonomy inherent in such approaches [23], [24]. The findings of the present study confirm this tension: while students valued the authenticity and creative freedom of the project task, they also reported uncertainty regarding time management, task prioritization, and expectations.

Thus, the core pedagogical problem identified in the first action research cycle was not the suitability of PBL itself, but the misalignment between project complexity and students’ developmental readiness, a challenge also noted in prior studies on design-based learning [23], [26].

Adjustments between action research cycles. In response to reflections from the first cycle, the second cycle introduced several pedagogical adjustments: clearer intermediate milestones, more explicit structuring of the design process, increased formative feedback, and stronger alignment between project tasks and parallel courses. These changes reflect recommendations from the literature emphasizing the importance of structured guidance in early-stage project-based learning [22], [23].

According to Phothong et al. [23], design-based learning is most effective when students are supported in understanding the sequence of design activities, from problem definition to prototyping and evaluation. The adjustments implemented in the second cycle operationalized these principles within the specific institutional context of the study.

Evidence of improvement and effectiveness of the intervention. Evidence of improvement was obtained through triangulation of student group discussions,

lecturer reflections, and observations of project outcomes. Compared to the first cycle, students in the second cycle demonstrated a clearer understanding of the stages of the design process, more systematic use of design research methods, and increased confidence in prototyping and presenting their ideas. These findings are consistent with previous research showing that structured project-based and design-based learning enhances students' problem-solving abilities, design thinking, and collaborative skills [27], [24], [28].

Lecturers also observed improved communication, more focused questions, and greater student engagement throughout the semester. Wei et al. [24] highlight that the development of design competence is closely linked to students' ability to deal with ambiguity through guided exploration and reflection, which was also evident in the present study after the pedagogical adjustments were introduced.

Collaboration and interdisciplinary learning. The study further confirms the importance of collaboration in project-based design education. Cooperation with engineers and research center specialists enabled students to apply technologies such as 3D printing and laser processing, supporting the interdisciplinary nature of design practice [29]. Previous research emphasizes that such collaboration enhances students' understanding of the relationship between aesthetics, technology, and sustainability [29], [25]. The findings of this study support these conclusions, showing that interdisciplinary cooperation contributed to both technical skill development and increased student motivation.

Positioning within action research and design pedagogy. Consistent with the principles of action research, the study did not aim to generalize findings but to improve pedagogical practice within a specific context through iterative cycles of planning, action, observation, and reflection. The results demonstrate how theoretical principles of project-based and design-based learning [22], [25], and [24] can be translated into context-sensitive pedagogical decisions that respond to students' needs.

Next steps in the action research spiral. In line with the action research spiral, future cycles will focus on further refining assessment criteria for process-oriented learning outcomes, strengthening interdisciplinary collaboration, and examining how early experiences with guided project-based learning influence students' design competence and professional identity in later stages of their studies. Longitudinal research has been identified in previous studies as a valuable approach for understanding the sustained impact of design education interventions [24], [26].

6 CONCLUSIONS

This action research study examined how a project-based learning approach can be iteratively improved to better support first-year design students. The research addressed a concrete pedagogical problem: the challenge students face when engaging in complex, open-ended design projects without sufficient experience in self-regulated learning and design process management.

The findings demonstrate that targeted pedagogical adjustments, such as clearer structuring of the design process, intermediate evaluations, and enhanced formative feedback, can significantly improve students' ability to engage meaningfully with project-based learning. These interventions supported the development of design thinking, collaboration, and reflective practice while maintaining the creative openness essential to design education.

Rather than aiming for generalization, this study contributes practice-based knowledge by illustrating how action research can function as an effective framework for pedagogical improvement in design studies. The results highlight the importance of aligning project complexity with students' developmental stage and emphasize the role of iterative reflection in refining teaching strategies.

The study primarily relied on qualitative, process-oriented data, which provides rich insight into pedagogical change but does not allow for causal claims or generalizable measurements of learning outcomes. The findings are situated within a specific institutional, curricular, and cultural context of design education. Differences in institutional structures, teaching traditions, or student profiles may lead to different outcomes when applying a similar project-based learning approach.

Future cycles of action research should focus on longitudinal effects, broader institutional contexts, and mixed-method approaches to further strengthen the evidence base for project-based learning in design education. In this way, the study positions action research not only as a research method but also as an ongoing pedagogical strategy for responsive and sustainable curriculum development.

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