Integrating Flipped Classroom and Project-Based Learning in IoT Education: Enhancing Academic Achievement and Self-Regulated Innovation Skills

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***Abstract*—In an undergraduate Internet of Things (IoT) course, this study examines the efficacy of combining Flipped Classroom (FC) with Project-Based Learning (PBL) in order to improve academic performance and self-regulated innovation abilities. The educational model was executed throughout a whole semester with third-year computer science students at Suan Sunandha Rajabhat University. Students engaged with pre-class content via digital platforms and utilized their knowledge throughout in-class prototype sessions and collaborative IoT project creation. A mixed-methods study approach was employed, integrating both quantitative and qualitative tools, such as pre- and post-tests, rubric-based project assessments, self-evaluation surveys, satisfaction questionnaires, and reflective journals. The results indicate significant enhancements in students' conceptual comprehension of IoT, practical competencies in system development, and vital soft skills including collaboration, communication, and innovative problem-solving. Qualitative data from reflections and observations indicated an enhancement in learners' autonomy, motivation, and adaptability—qualities linked to self-regulated innovation. Students indicated substantial satisfaction with the teaching methodology, highlighting that the combination of flexibility, cooperation, and real-world applicability enhanced the significance of their learning experience. The study suggests that the Flipped Project-Based Learning (FPBL) model is a viable pedagogical approach for IoT education, fostering both technical proficiency and innovation-driven skill enhancement. Recommendations encompass the broadening of FPBL implementation within technical courses, the provision of organized scaffolding for beginner learners, and the cultivation of instructional settings that promote creativity and self-directed learning.**

***Keywords*—internet of things, active learning, self-regulated learning, project-based, flipped learning**

I. Introduction

The Internet of Things (IoT) is a swiftly advancing domain that necessitates learners to comprehend intricate technical systems and cultivate the capacity to address real-world challenges through transdisciplinary expertise. The instruction of IoT in higher education poses distinct obstacles, as it frequently necessitates the amalgamation of hardware, software, data analytics, and networking principles within a constrained timeframe. Traditional lecture-based methods, although beneficial for core knowledge, may inadequately foster the acquisition of crucial 21st-century abilities such problem-solving, communication, cooperation, and flexibility [1, 2]. This has prompted educators to investigate more engaging and learner-centered pedagogies to improve both conceptual comprehension and practical proficiency in IoT.

Project-Based Learning (PBL) and the Flipped Classroom (FC) model are among the most promising active learning methodologies. Project-Based Learning engages students in significant, practical projects that require them to identify issues, devise solutions, and provide concrete results. This methodology promotes independence, analytical reasoning, and collaboration [3–6]. The Flipped Classroom concept inverts the conventional teaching framework by providing theoretical knowledge outside of class—usually via videos or digital resources—while allocating class time for discussion, collaboration, and practical application [7, 8]. When effectively integrated, these methodologies can cultivate a comprehensive learning environment that fosters profound understanding, practical involvement, and the enhancement of professional competencies pertinent to IoT [9, 10].

This research was conducted within a third-year undergraduate course entitled "Internet of Things," provided to computer science students at Suan Sunandha Rajabhat University during the second semester of the 2024 academic year. The course spanned 14 weeks and comprised 65 students, segmented into two portions of 33 and 32 students, respectively. The instructional design incorporated both project-based learning and flipped classroom methodologies, enabling students to participate in practical projects while obtaining theoretical content via asynchronous online resources.

Despite the growing implementation of active learning models in Science, Technology, Engineering and Mathematics (STEM) education, a significant lack persists in empirical research specifically addressing IoT courses that incorporate both PBL and FC frameworks. Furthermore, although the efficacy of these methods has been extensively proven in general engineering and computing education, their influence on the development of soft skills—such as self-management, communication, and teamwork—within the realm of IoT remains inadequately investigated. This study examines the effects of implementing Project-Based Learning and Flipped Classroom methodologies in an undergraduate IoT course, emphasizing academic performance and the development of soft skills.

This study aims to fill these gaps by examining the effects of integrating Flipped Classroom with Project-Based Learning (FPBL) on learning outcomes in IoT education and the three main research questions it aims to investigate are (1) how the FPBL approach affects students' academic performance in an IoT course; (2) how much this instructional model encourages the development of self-regulated innovation skills; and (3) how students view and react to the FPBL-shaped learning experience. Deeper understanding of the instructional potential of FPBL in preparing students with both technical knowledge and critical 21st-century competences is the goal of these investigations.

II. Literature Review

Comprehending the effective application of pedagogical innovations such as Project-Based Learning (PBL) and the Flipped Classroom (FC) model in intricate, multidisciplinary domains like the Internet of Things (IoT) is crucial, particularly given the increasing focus on active learning in higher education, especially within STEM fields. This section establishes the theoretical framework for the present study by analyzing previous research on active learning, the educational significance of Project-Based Learning (PBL) and Flipped Classrooms (FC), and their incorporation into Internet of Things (IoT) education and other domains.

Active learning indicates pedagogical approaches that involve students in activities such as cooperation, problem-solving, and self-reflection, rather than mere passive reception of information. An increasing volume of evidence indicates that active learning markedly improves students' understanding, retention, and application of knowledge in STEM disciplines [11, 12]. Prince [13] asserted that active learning enhances academic performance and fosters profound conceptual comprehension, particularly in technical fields necessitating practical problem-solving skills.

Persky and McLaughlin [14] examined the theoretical foundations of the flipped classroom in health professional education and presented a systematic implementation approach that encompasses pre-class, in-class, and post-class activities, as well as assessment methodologies. The IoTFLiP platform [15] illustrates that utilizing IoT infrastructure within a flipped, case-based learning methodology enhances decision-making and promotes collaboration among medical students by providing exposure to authentic clinical scenarios.

In computing, IoT prototyping within a PBL framework has demonstrated efficacy in integrating fundamental computer science principles into genuine learning experiences. Regardless of the diverse student experiences and variable project difficulties, a cohesive and efficient assessment strategy has been employed to evaluate individualized learning outcomes [16].

The amalgamation of flipped classroom methodologies with IoT-centric activities in contemporary C++ programming education has demonstrated an enhancement in student motivation, active engagement, and the cultivation of lifelong learning habits, especially in domains involving modern tools such as templates, concurrency, and smart pointers [17].

In addition to demonstrating the value of auxiliary technologies like Learning Management Systems (LMS), video production tools, and collaborative platforms, a systematic review of 30 studies published between 2014 and 2023 demonstrates that flipped learning enhances educational outcomes in higher education across all subject areas [18]. Notwithstanding its benefits, the assessment recognized implementation issues including content quality and instructor readiness, providing pragmatic solutions to surmount these obstacles.

From a comprehensive policy standpoint, the incorporation of IoT in higher education is acknowledged as revolutionary, impacting both pedagogical methods and the enhancement of educational infrastructure, especially in knowledge-based countries such as Kenya. Institutions are urged to prioritize scalable IT investment, change organizational architecture, and foster privacy-conscious innovation to adapt to the requirements of digital education [19].

Furthermore, flipped classroom approaches that include blended learning and reflective practices have been shown to markedly improve students' self-regulation and personal development—two critical soft skills in the context of Industry 4.0 [20, 21]. Recent study indicates that Flipped Project-Based Learning (FPBL) enhances students' motivating beliefs, autonomy, and metacognitive skills across several disciplines.

Köpeczi-Bócz [22] conducted a comprehensive study across higher education institutions, revealing that the integrated implementation of Project-Based Learning (PBL) and Flipped Classroom (FC) methodologies significantly enhanced student motivation and academic performance at both undergraduate and vocational education levels. These findings corroborate previous studies emphasizing the significance of digital learning platforms—such as Google Classroom—in enhancing student engagement and fostering active learning practices. Chutrtong *et al.* [23] indicated that students regarded Google Classroom as an effective instrument for communication, resource accessibility, and time management—elements essential in the flipped learning phase of the FPBL approach and this study builds on previous research in blended programming education by integrating digital platforms with flipped and project-based tactics to enhance engagement and promote innovation-oriented learning outcomes [24]. According to recent studies, flipped classroom strategies are becoming more and more popular as a way to improve student engagement, especially in the teaching of English as a Foreign Language (EFL) and English for Specific Purposes (ESP). Zhang [25] conducted a quasi-experimental investigation in an online ESP course, which revealed that flipped teaching significantly enhanced students' behavioral and cognitive engagement, with the main factors being teacher presence and task design. Likewise, Li *et al.* [26] emphasized in a mini-review that learner engagement in flipped EFL contexts is a multifaceted, context-dependent term that encompasses behavioral, cognitive, emotional, and social aspects. Although flipped instruction generally encouraged active involvement and cognitive effort, the authors stressed that the consequences of emotional engagement varied and were impacted by instructional design and learner readiness. To further elaborate, Liu *et al.* [27] assessed a flipped college English course and found that while emotional engagement did not change statistically, behavioral, cognitive, and social engagement all significantly improved. Their findings suggest that while flipped classrooms may boost multidimensional participation, we must meticulously address challenges related to workload and emotional support. All of this research highlights the educational possibilities of flipped models and offers insightful information for creating dynamic, learner-centered settings. This research demonstrates the educational potential of flipped approaches and provides valuable insights to create dynamic, learner-centered environments. Furthermore, Samala *et al.* [28] performed a comprehensive assessment of Emerging Technologies (ETs) in formal education, revealing both advantages and obstacles. Although solutions such as AI, IoT, and LMS improve learning accessibility and customization, problems persist, including infrastructural deficiencies and inadequate digital literacy and the research underscores the capability of adaptive systems to facilitate personalized learning. The reviewed literature demonstrates compelling evidence that the integration of PBL and FC techniques improves cognitive outcomes and soft skills in higher education, particularly when combined with emerging technologies like IoT. These methodologies promote active participation, individualized education, and professional skills pertinent to the requirements of Industry 4.0.

Although earlier studies have shown that project-based learning (PBL), Flipped Classroom (FC), and student success are linked positively, more specific research is needed to see how PBL and FC can be effectively used together in teaching IoT to university students in Thailand. This study investigates the pedagogical efficacy of a hybrid FPBL paradigm to improve academic performance and innovation-related skills among Thai university students.

III. Materials and Methods

This section outlines the research design, participants, instructional intervention, data collection instruments, and data analysis methodologies employed to examine the effects of the integrated Project-Based Learning and Flipped Classroom approach in an undergraduate IoT course.

A. Research Design

This research utilized a quasi-experimental mixed-methods approach to examine the impact of a Flipped Project-Based Learning (FPBL) teaching model on students' academic performance and self-regulated innovation skills in an undergraduate Internet of Things (IoT) course. The approach was selected to encompass both the quantitative effects on learning outcomes (e.g., test scores, project assessments) and qualitative insights on behavioral and motivational transformations among students.

The quantitative aspect concentrated on evaluating pre-test and post-test outcomes, project rubric evaluations, and self-assessment information. A one-group pretest-posttest design was employed, as all students participated in the intervention. Descriptive statistics, paired sample t-tests, and effect size (Cohen's d) were employed to assess variations in academic achievement.

The qualitative component encompassed open-ended reflections, classroom observations, and peer assessments to examine the impact of the FPBL model on students' cultivation of soft skills and self-regulated learning practices. The data were thematically examined to discern trends in students' involvement, problem-solving, and autonomous learning practices.

The integration of both methodologies facilitated a thorough comprehension of the instructional intervention's impact and enabled data triangulation to enhance the validity of the results.

B. Participants

The participants comprised 65 third-year undergraduate students enrolled in the IoT course during the second semester of the 2024 academic year at the Computer Science Department of Suan Sunandha Rajabhat University. Students were categorized into two groups: Section A (33 students) and Section B (32 students). All students engaged in the intervention utilizing the identical educational model.

C. Course Design and Instructional Intervention

The course covered 14 weeks and was organized around essential components to facilitate active learning and project-based involvement:

- Pre-class learning: Students accessed asynchronous educational materials, including video lectures, prescribed readings, and interactive quizzes, all facilitated by the Google Classroom platform. This phase enabled students to acquire core knowledge at their own speed prior to attending class.
- In-class activities: Weekly in-person meetings prioritized student engagement and practical application. Each course included practical laboratory sessions, comprising a total of 8 lab-based workshops during the semester. These laboratories emphasized fundamental IoT competencies, including sensor integration, data transmission, microcontroller programming, and cloud connectivity. Students participated in collaborative conversations, peer evaluations, and immediate problem-solving with instructor support.
- Project-Based Assessment: Students were organized into small groups and tasked with collectively designing and constructing an IoT prototype that addresses a real-world issue. During the semester, groups enhanced their answers based on feedback from peers and the instructor. During the concluding weeks, each group showcased and exhibited their finalized project. The assessment was conducted using a well-defined rubric that included technical functionality, innovation, collaboration, and presentation efficacy.
- The course instructor created a criteria to assess student projects in four important areas: creativity, technical operation, problem-solving, and teamwork. In order to guarantee clarity and contextual relevance, the rubric was improved through pilot testing in prior course offerings and guided by recognized frameworks for 21st-century abilities.
- The course instructor performed a thematic analysis, going over each student's reflection and finding recurrent themes pertaining to independent learning, collaboration, and creative thinking. After several rounds of evaluation, the themes were honed, and significant findings were illustrated using representative quotes. Although only one rater coded, documentation and reflection were used to guarantee uniformity and rigor.

Fig. 1 demonstrates the instructional framework developed for the amalgamation of Flipped Classroom and Project-Based Learning (PBL) methodologies in an Internet of Things (IoT) course. The concept comprises three essential phases: pre-class activities, in-class activities, and project execution. During the pre-class phase, students participate in video lectures and complete designated readings and quizzes remotely, enabling them to establish foundational knowledge before class. The in-class phase prioritizes experiential learning via project development, collaborative engagement among peers, and immediate feedback from instructors. The IoT project phase entails collaborative efforts among students to address real-world challenges and deliver their solutions. These three instructional components jointly enhance the cultivation of self-regulated innovation skills, empowering students to autonomously oversee their learning, engage in creative thinking, and produce inventive solutions—essential competencies for Industry 4.0. This integrated course design aimed to promote profound learning, collaboration, autonomy, and the application of multidisciplinary knowledge in practical contexts.

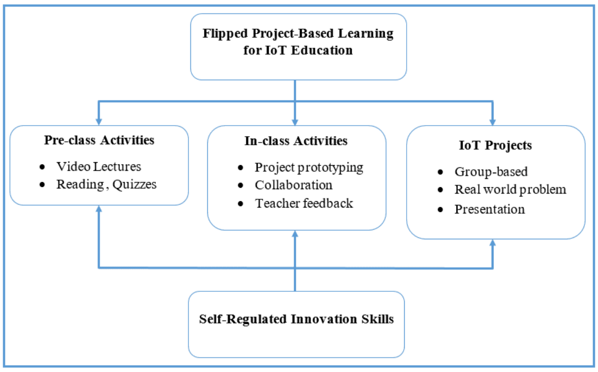

Fig. 1. Flipped project-based learning in IoT education framework.

D. Data Collection Instruments

Data was gathered from multiple sources using a variety of instruments (Table 1):

Table 1. Instruments and descriptions for data collection

Instrument	Description
Pre-test/Post-test	A 20-item multiple-choice examination evaluating students' conceptual understanding of the Internet of Things (IoT).
Project Rubric Scores	The evaluation criteria encompassed functionality, creativity, collaboration, and presentation.
Student Self-Assessment	Survey on self-regulated learning (SRL), motivation, and collaboration
Student Satisfaction Survey	5-point Likert scale assessing perceived value and engagement
Classroom Observations & Reflections	Weekly thoughts and instructor observations documenting behavioral insights

E. Data Analysis Methods

Quantitative and qualitative analysis methodologies were utilized to assess the efficacy of the instructional intervention and to address the study issues concerning academic performance and self-regulated innovation skills.

1) Quantitative analysis

Quantitative data obtained from pre-test and post-test scores, project rubric evaluations, self-assessment questionnaires, and satisfaction surveys were examined utilizing the subsequent statistical methods:

- Descriptive statistics, including mean, Standard Deviation (SD), and percentage, were calculated to encapsulate overall performance, perceptions, and skill evaluations.
- Paired Sample t-Test: Utilized to evaluate significant differences between pre-test and post-test results to measure learning advancements.
- Effect Size (Cohen's d): Computed to assess the extent of the intervention's influence on cognitive results.
- Rubric Analysis: Project scores were evaluated by rubric category (functionality, innovation, teamwork, and presentation) to ascertain strengths and areas for enhancement.
- Categorical Distribution: Project ratings were classified into four performance tiers (Fair, Good, Very Good, and Excellent) for frequency analysis.

2) Qualitative analysis

Qualitative data from open-ended student responses and classroom observation notes were subjected to thematic analysis to discern reoccurring themes pertaining to:

- Self-regulated learning behaviors
- Innovative methodologies
- Group dynamics and cooperation
- Obstacles encountered throughout the duration

The themes were coded and analyzed to enhance the quantitative results and offer a more profound understanding of how the instructional approach facilitated students' soft skill development and real-world problem-solving ability.

The combination of quantitative and qualitative methodologies facilitated data triangulation, improved validity, and provided a comprehensive picture of the educational consequences.

Prior to the study, ethical approval was acquired, and all operations followed the institutional ethical guidelines and participants were informed of the study's objectives and methodologies and granted their explicit consent before participation. Their identities and responses were maintained in absolute confidentiality and anonymized in all reports and analyses. Additionally, participants were guaranteed the ability to resign from the study at any point without facing any academic or personal repercussions.

IV. Result and Discussion

This section explores the outcomes of the instructional intervention and examines their implications concerning the research objectives. The results are categorized into four primary dimensions: (A) academic achievement, (B) project performance, (C) self-regulated innovation skills, and (D) student satisfaction.

A. Academic Achievement

When pre-test and post-test results were compared, it was shown that students' conceptual grasp of IoT had significantly improved. The average pre-test score was 12.29 (SD = 2.32), whereas the average post-test score increased to 16.39 (SD = 1.92). A paired sample t-test indicated a statistically significant difference (t (64) = 9.32, $p < 0.001$), with a computed Cohen's d = 1.16, denoting a large effect size and implying a substantial influence of the FPBL model on cognitive learning outcomes. Fig. 2 shows a significant increase in students' average scores from the pre-test to the post-test, indicating improved understanding after the FPBL intervention.

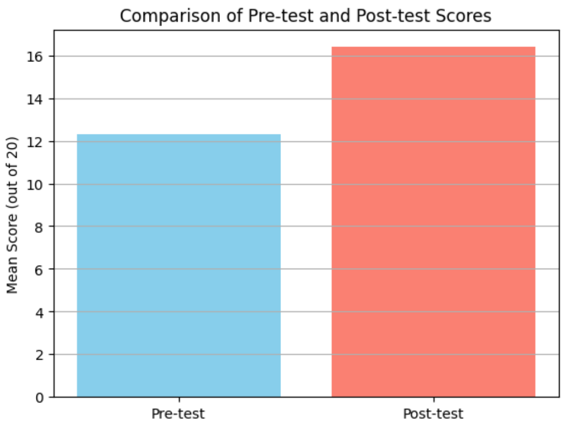

Fig. 2. Comparison of pre-test and post-test scores.

These results corroborate earlier studies [12, 14] demonstrating the efficacy of flipped and project-based learning in improving comprehension and information retention, especially in technical fields such as STEM and IoT.

B. Project Performance

When assessed using standardized criteria, final project scores showed that students in all teams performed at a high level. The average project score was 86.3 out of 100, indicating a robust application of academic knowledge to practical problem-solving. Upon classification, 69% of students attained a performance level designated as “Excellent,” 23% as “Very Good,” and merely 8% were rated within the “Good” or lower range as presented in Fig. 3.

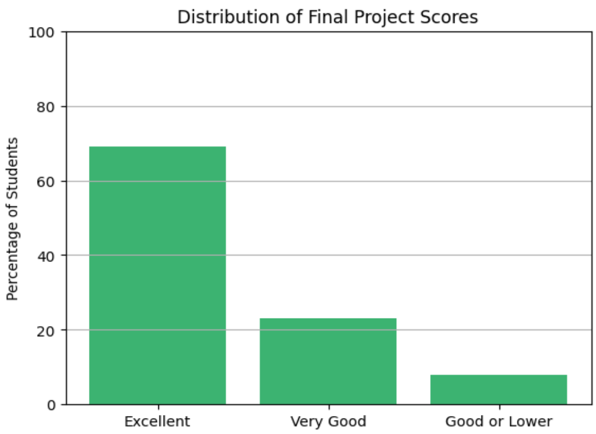

Fig. 3. Distribution of final project scores.

Students performed notably in the teamwork and functionality aspects of the rubric, indicating their capacity to collaboratively design, create, and showcase operational IoT solutions. The variety of project topics—spanning environmental monitoring, smart home automation, safety detection, and sensor-based alert systems—exhibited both ingenuity and applicability to real-world issues. Numerous organizations effectively amalgamated hardware components (e.g., sensors, microcontrollers), networking tools, and user interfaces to produce comprehensive and operational prototypes.

These results highlight the importance of project-based learning in IoT education, especially in fostering system-level thinking, collaborative innovation, and applied technical skills—all of which are critical proficiencies for aspiring engineers and technologists.

According to Fig. 4, students presented their group-based IoT prototypes during the final week of the course. The projects integrated real-world problem-solving with embedded systems, as seen in the live demonstration of hardware components and sensor functionality. The audience included peers and instructors who provided immediate feedback and evaluation.

(a)

(b)

Fig. 4. Student IoT project presentation in a final showcase session. (a) Topic introduction; (b) Project descriptions.

C. Self-Regulated Learning and Soft Skills

The self-assessment questionnaire results indicated significant improvement in essential innovation-related soft skills among students. Students evaluated their competencies on a 5-point Likert scale, with the greatest self-assessment in teamwork ($M = 4.32$), followed by communication ($M = 4.26$), creative problem-solving ($M = 4.19$), self-motivation ($M = 4.16$), and time management ($M = 4.06$) as illustrated in Fig. 5.

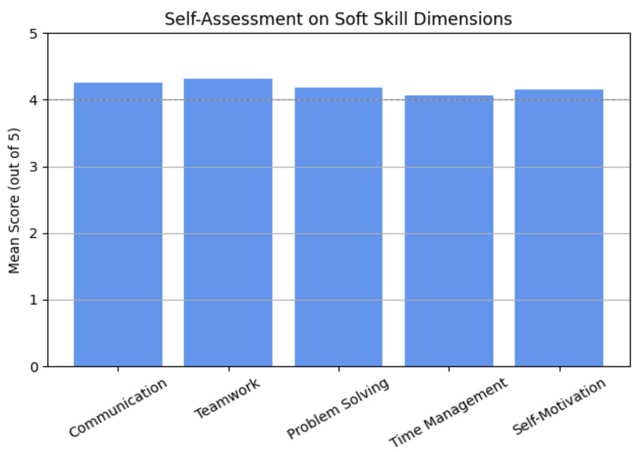

Fig. 5. Self-assessment on soft skill dimensions.

The scores demonstrate that the Flipped Project-Based Learning (FPBL) environment successfully enhanced learners’ ability to collaborate, engage in critical thinking, and manage their innovation process with limited external guidance [18, 20].

The course design promoted independence and initiative by giving students the responsibility of setting their own project objectives, allocating team responsibilities, controlling time limits, and iteratively refining their work in response to performance evaluations. These behaviors correspond with the notion of self-regulated innovation, wherein learners not only perform designated tasks but also actively manage their learning and development within the innovation cycle.

Qualitative data derived from student reflections and instructor observations corroborated these findings. Numerous students reported having to deal with unanticipated technical problems including sensor calibration, wireless data transmission malfunctions, or unplanned power supply interruptions. Instead of depending solely on instructor support, teams frequently engaged in own research, solicited peer feedback, and explored alternate ideas. This capacity to endure challenges, adapt techniques, and synchronize team efforts was continually evident across project milestones.

Furthermore, a shift in the students' perspective from passive learners to active problem solvers was observed in a number of reflection entries. Several teams expanded project features beyond the original specifications, incorporating cloud-based dashboards and mobile app interfaces, demonstrating innovative enhancement and design accountability.

The integration of quantitative self-assessment and qualitative reflection offered a comprehensive perspective on the effectiveness of the FPBL paradigm in fostering self-directed, innovative learners adept at applying their knowledge to evolving real-world situations.

D. Student Satisfaction

The post-course satisfaction survey results indicated a highly favorable student experience with the Flipped Project-Based Learning (FPBL) paradigm. The overall course satisfaction was scored at $M = 4.39$ (SD = 0.62) on a 5-point Likert scale, signifying that the majority of students perceived the course as very engaging, pertinent, and conducive to their learning experience.

Students indicated notably heightened satisfaction in three primary domains:

1) The adaptability of flipped content

Many students valued the opportunity to examine video lectures and online resources at their own pace prior to class. This flexibility enabled students to review intricate topics, pause for elucidation, and take notes autonomously, thus alleviating tension and enhancing preparedness for practical in-class activities.

2) Genuineness of the project experience

The open-ended, real-world characteristics of the IoT projects were often regarded as an asset. Students indicated their appreciation for engaging in practical challenges that reflected authentic professional activities, including the development of sensor-based systems, the integration of mobile applications, and the resolution of context-specific issues (e.g., environmental monitoring, security, or automation). This apparent authenticity rendered the learning process more significant and influential.

3) Relevance of acquired talents

The majority of students reported that the course equipped them with transferable abilities such as teamwork, time management, and problem-solving. They indicated that they now possess greater confidence in implementing IoT technologies in practical applications—specifically in hardware prototyping, circuit design, and cloud connectivity—compared to previous lecture-based courses.

In open-ended comments, students emphasized an enhanced sense of ownership over their learning, which inspired them to remain engaged even throughout challenging technical phases. The majority of students indicated a preference for implementing this teaching approach in additional courses, highlighting that the integration of practical projects, adaptable pre-class learning, and collaborative peer interactions enhanced the educational experience's engagement and significance.

Several students suggested enhancements, including the provision of preliminary lessons for hardware tools and increased peer-sharing sessions. Nevertheless, the general sentiment of the comments was exceedingly favorable, affirming that the FPBL paradigm enhanced both academic and technical results while also fostering a gratifying and empowering educational experience.

E. Discussion

The findings of this research strongly support the ideas of active learning, highlighting the importance of student involvement, taking charge of their own learning, and creating knowledge through meaningful activities. Furthermore, the significant improvement in understanding, shown by the post-test results (Cohen's $d = 1.16$), demonstrates the cognitive benefits of the FPBL model. Students independently participated in pre-class learning, equipping them for more intricate, collaborative problem-solving activities during in-class sessions. Furthermore, this supports [1] claim that active learning improves academic achievement, particularly in STEM fields that necessitate the actual application of information. Students' performance on project-based assignments most clearly demonstrates the concepts of experiential learning. Besides technical expertise, their capacity to convert theoretical knowledge into practical IoT systems, ranging from environmental monitoring to smart home automation, represents creativity and critical thinking. Active learning environments promote deep learning experiences that include these essential characteristics. Furthermore, students were empowered to assume responsibility, negotiate concepts, and progressively refine their responses through the hands-on, collaborative nature of project work, all of which reinforce a constructivist learning approach. Enhancing competencies such as self-motivation, strategic planning, adaptability, and reflective problem-solving demonstrates that the FPBL approach encourages learner independence, as the majority of students assumed responsibility for their education by actively addressing technical challenges, managing team dynamics, and refining project properties. These acts use cognitive skills, which is a key part of active learning, in which students take charge of and monitor their education.

Furthermore, the statistics on student satisfaction emphasize the emotional and social aspects of engagement. Their ability to set their own pace for pre-class preparation thanks to the flexible structure of flipped learning made them less anxious and more ready for tasks in class. Students demonstrated social engagement when they collaborated and supported each other. This finding supports research by Li *et al*. [26, 27], which emphasizes that peer interaction and environmental factors are important in flipped EFL classes. To maintain learner engagement, the FPBL model's combination of autonomy and cooperation fostered a sense of purpose and significance. Essentially, the FPBL method implemented numerous elements of active learning. It needed students to plan ahead, think critically, work together, reflect all the time, and be responsible for the results. These results show that using flipped instruction along with project-based tasks can make learning environments that are dynamic and focused on the user that are perfect for the needs of Industry 4.0 education. Even though the results were highly satisfactory, some students said that they experienced trouble getting used to open-ended learning at first, which shows they need organized scaffolding. Facilitate the transition of students into autonomous, innovation-driven learning models, future iterations of the course could include mentorship components, explicit project checkpoints, and introductory modules.

V. Conclusion

As a successful instructional paradigm for improving learning outcomes in undergraduate Internet of Things (IoT) education, this study offers empirical evidence in favor of the merging of Flipped Classroom and Project-Based Learning (FPBL). The results indicate that FPBL enhances students' comprehension of IoT ideas and system design while cultivating vital 21st-century skills, such as collaboration, communication, problem-solving, and self-directed innovation abilities.

The FPBL approach merges the adaptability of asynchronous pre-class learning with the organization and authenticity of in-class, project-based collaboration, resulting in a highly engaging and student-centered educational environment. Students evolved into more engaged, independent learners proficient in managing practical technical assignments while collaborating with classmates. Reflection data indicated heightened motivation and confidence among students to address intricate difficulties and modify their tactics over time.

The instructional model is closely matched with the skill requirements of Industry 4.0, where professionals must possess technical understanding as well as the capacity for innovation, adaptability, and constant learning. The favorable student feedback, robust project results, and enhancement of soft skills indicate that FPBL may function as a sustainable and scalable educational framework for higher education in engineering and technology disciplines.

1) Implications for Practice:
- Educators are urged to adopt FPBL models in additional technical fields to enhance profound learning and student involvement.
- Institutions ought to provide instructors with tools and training for the creation of digital learning materials, the facilitation of experiential learning, and the evaluation of innovation-oriented competencies.
- Future instructional designs may increasingly include emerging technology (e.g., dashboards, analytics, AI tutors) to personalize and improve the FPBL experience.

2) Future Research Directions:
- To confirm that the results are generalizable, compare studies across multiple cohorts or institutions
- Future research should incorporate control or comparison groups to strengthen internal validity and bolster more robust causal conclusions about the efficacy of the FPBL model.
- Evaluate the enduring use of acquired skills in professional or internship settings.
- Develop and verify evaluation models that measure both cognitive function and results focused on innovation.

While most previous research on Internet of Things (IoT) education has focused on developing technical skills like programming, prototyping, or tool-specific training, this study makes a unique contribution by systematically combining Flipped Classroom (FC) and Project-Based Learning (PBL) into a single instructional framework called Flipped Project-Based Learning (FPBL). This framework's principal innovation is its explicit focus on cultivating self-regulated innovation abilities in conjunction with essential technical competencies inside an undergraduate IoT course, an aspect that has been significantly overlooked in IoT-related educational research.

The FPBL approach is designed to allow students to prepare on their own before class, followed by working together on projects during class, which helps them understand IoT systems better and develop important skills like teamwork, communication, problem-solving, and independent learning. These interpersonal skills are essential for equipping students to excel in the era of Industry 4.0, where adaptability, creativity, and lifelong learning are as vital as technical expertise.

Consequently, this study extends beyond only confirming the academic advantages of active learning methodologies. It presents a pedagogically sound and practically scalable framework for developing innovation-oriented learners in intricate and dynamic technical fields like IoT. The FPBL framework offers potential for enhancing engineering and technology education by synchronizing instructional design with the diverse skill requirements of contemporary industry.

In conclusion, the FPBL paradigm presents an exciting opportunity for revolutionizing IoT education by integrating knowledge with practice and fostering learners who are technically proficient, self-motivated, and prepared for creativity.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

NR and KK were responsible for the research design. NR conducted the data collection and contributed to data analysis. KB and KK were responsible for data analysis, writing, and

editing. All authors read and approved the final manuscript.

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REFERENCES

[1] M. Prince, "Does active learning work? A review of the research," *J. Eng. Educ.*, vol. 93, no. 3, pp. 223–231, Jul. 2004. doi: 10.1002/j.2168-9830.2004.tb00809.x

[2] M. M. Rahman, "21st century skill 'problem solving': Defining the concept," *Asian J. Interdiscip. Res.*, vol. 2, no. 1, pp. 64–74, Mar. 2019. doi: 10.34256/ajir1917

[3] J. W. Thomas. (2000). *A Review of Research on Project-Based Learning*. San Rafael, CA, USA: The Autodesk Foundation. [Online]. Available: http://www.bobpearlman.org/BestPractices/PBL_Research.pdf

[4] P. Guo, N. Saab, L. S. Post, and W. Admiraal, "A review of project-based learning in higher education: Student outcomes and measures," *Int. J. Educ. Res.*, vol. 102, 101586, May 2020. doi: 10.1016/j.ijer.2020.101586.

[5] G. Zou, Y. Xue, G. Chen, Z. Li, and X. Li, "Exploration of academic performance evaluation in project-based learning," *Open J. Social Sci.*, vol. 11, pp. 202–210, Aug. 2023. doi: 10.4236/jss.2023.118014.

[6] R. Gillies, "Cooperative learning: Review of research and practice," *Australian. J. Teach. Educ.*, vol. 41, no. 3, pp. 39–54, Mar. 2016. doi: 10.14221/ajte.2016v41n3.3

[7] L. Calimeris and K. M. Sauer, "Flipping out about the flip: All hype or is there hope?" *Int. Rev. Econ. Educ.*, vol. 20, pp. 13–28, Sep. 2015.

[8] S. Yamarik, "Flipping the classroom and student learning outcomes: Evidence from an international economics course," *Int. Rev. Econ. Educ.*, vol. 31, 100163, May 2019. doi: 10.1016/j.iree.2019.100163.

[9] K. G. Srinivasa and S. B. Bhat, "Project based learning for internet of things and data analytics: Experience report of learning from ET601X," in *Proc. 2016 IEEE 8th Int. Conf. Technol. Educ. (T4E)*, Mumbai, India, 2016, pp. 262–263. doi: 10.1109/T4E.2016.070

[10] P. Netinant, P. Narad, and M. Rukhiran, "A case study of project-based learning on Internet of Things course," in *Proc. 7th Int. Conf. Front. Educ. Technol. (ICFET'21)*, ACM, 2021, pp. 126–131. doi: 10.1145/3473141.3473237

[11] S. Freeman, S. L. Eddy *et al*., "Active learning increases student performance in science, engineering, and mathematics," in *Proc. Natl. Acad. Sci.,* U.S.A., 2014, vol. 111, no. 23, pp. 8410–8415. doi: 10.1073/pnas.1319030111

[12] C. Sangsuwon, S. Chopvitayakun, N. Aukkanit, and S. Sirichokworrakit, "Interactive game-based approach to learning the organic chemistry course," in *Proc. 2024 10th Int. Conf. e-Society, e-Learning and e-Technologies (ICSLT 2024)*, Rome, Italy, ACM, Jun. 21–23, 2024, pp. 1–6. doi: 10.1145/3678610.3678620

[13] A. M. Persky and J. E. McLaughlin, "The flipped classroom—From theory to practice in health professional education," *Am. J. Pharm. Educ.*, vol. 81, no. 6, 118, Aug. 2017. doi: 10.5688/ajpe816118

[14] M. Ali, H. S. M. Bilal, M. A. Razzaq, J. Khan, S. Lee, M. Idris *et al.*, "IoTFLiP: IoT-based flipped learning platform for medical education," *Digit. Commun. Netw*., vol. 3, no. 3, pp. 188–194, Aug. 2017. doi: 10.1016/j.dcan.2017.03.002

[15] H. Maenpaa, S. Varjonen, A. Hellas, S. Tarkoma, and T. Mannisto, "Assessing IoT projects in university education—A framework for problem-based learning," in *Proc. IEEE/ACM Int. Conf. Softw. Eng.: Software Eng. Educ. Training (ICSE-SEET)*, Buenos Aires, Argentina, 2017, pp. 37–46. doi: 10.1109/ICSE-SEET.2017.6

[16] M. I. Baig and E. Yadegaridehkordi, "Flipped classroom in higher education: A systematic literature review and research challenges," *Int. J. Educ. Technol. High. Educ*., vol. 20, no. 61, 2023. doi: 10.1186/s41239-023-00430-5

[17] U. Schäfer, "Teaching modern C++ with flipped classroom and enjoyable IoT hardware," in *Proc. IEEE Global Eng. Educ. Conf. (EDUCON)*, Dubai, UAE, 2019, pp. 910–919. doi: 10.1109/EDUCON.2019.8725068

[18] A. M. Persky and J. E. McLaughlin, "The flipped classroom—From theory to practice in health professional education," *Am. J. Pharm. Educ*., vol. 81, no. 6, 118, Aug. 2017. doi: 10.5688/ajpe816118

[19] N. Lyz, A. Lyz, I. Neshchadim, and V. Kompaniets, "Blended learning and self-reflection as tools for developing IT-students' soft skills," in *Proc. 2020 V Int. Conf. Inf. Technol. Eng. Educ. (Inforino)*, Moscow, Russia, 2020, pp. 1–4. doi: 10.1109/Inforino48376.2020.9111723

[20] N. Letting and J. Mwikya. Internet of Things (IoT) and quality of higher education in Kenya: A literature review. [Online]. Available: https://core.ac.uk/download/pdf/286894462.pdf

[21] M. Y. Zarouk, E. Olivera, P. Peres, and M. Khaldi, "The impact of flipped project-based learning on self-regulation in higher education," *Int. J. Emerg. Technol. Learn.*, vol. 15, no. 17, pp. 127–147, Sep. 2020.

[22] T. Köpeczi-Bócz, "The impact of a combination of flipped classroom and project-based learning on the learning motivation of university students," *Educ. Sci.*, vol. 14, no. 3, 240, 2024. doi: 10.3390/educsci14030240

[23] J. Chutrtong, S. Sirichokworrakit, and K. Kularbphettong, "Students' perceptions of using Google Classroom in General Microbiology course," in *Proc. 2024 10th Int. Conf. e-Society, e-Learning and e-Technologies (ICSLT 2024)*, ACM, Rome, Italy, Jun. 21–23, 2024, pp. 1–5. doi: 10.1145/3678610.3678615

[24] K. Kularbphettong, N. Raksuntorn, S. Kumchoo, and C. Boonseng, "Assessing programming language teaching during COVID-19 with blended learning," in *Proc. 2024 10th Int. Conf. e-Society, e-Learning and e-Technologies (ICSLT 2024)*, ACM, Rome, Italy, Jun. 21–23, 2024, pp. 1–5. doi: 10.1145/3678610.3678614

[25] Z. Li and Y. Wang, "Adopting online flipped teaching to improve learner engagement in an English for Specific Purposes (ESP) course in China: a mixed-methods study," *Journal of China Computer-Assisted Language Learning*, vol. 3, no. 2, Apr. 2023, pp. 335–361. https://doi.org/10.1515/jccall-2023-0001

[26] Z. Li, and J. Li, "Learner engagement in the flipped foreign language classroom: Definitions, debates, and directions of future research," *Front. Psychol*, vol. 13, 810701, Jul. 2022. doi: 10.3389/fpsyg.2022.810701

[27] Z. Li and J. Li, "Using the flipped classroom to promote learner engagement for the sustainable development of language skills: A mixed-methods study," *Sustainability*, vol. 14, no. 10, 5983, May 2022, https://doi.org/10.3390/su14105983

[28] A, D. Samala, S. Rawas, S. Criollo-C, L. Bojic, F. Prasetya, F. Ranuharja *et al.*, "Emerging technologies for global education: A comprehensive exploration of trends, innovations, challenges, and future horizons," *SN Comput. Sci*. vol. 5, no. 8, Dec. 2024. https://doi.org/10.1007/s42979-024-03538-1