Journal of Education and Learning; Vol. 14, No. 4; 2025
ISSN 1927-5250 E-ISSN 1927-5269
Published by Canadian Center of Science and Education

A Comparative Study on the Effects of Project-Based Learning and Online Lessons on the Learning Achievement on the Internet of Things Among Thai Grade 9 Students

Rattikan Sarnkong[1], Kamonchanok Kamnuay[1], Wanicha Sakorn[1] & Naowarut Pakinumhung[2]

[1] Faculty of Education, Rajabhat Maha Sarakham University, Thailand

[2] Sarakhampittayakhom School, Thailand

Correspondence: Wanicha Sakorn, Faculty of Education, Rajabhat Maha Sarakham University, Thailand 44000.

Received: November 21, 2024 Accepted: January 31, 2025 Online Published: February 25, 2025

doi:10.5539/jel.v14n4p136 URL: https://doi.org/10.5539/jel.v14n4p136

Abstract

This study aimed to compare the effects of project-based learning (PjBL) and online lessons on the learning achievement of Thai Grade 9 students in the topic of the Internet of Things (IoT), with conventional teaching included as a control group. The study utilized a quasi-experimental design, with three groups: PjBL, online lessons, and conventional teaching. The participants included 125 Grade 9 students from a secondary school in Thailand, divided into three groups: 42 in the PjBL group, 41 in the online lessons group, and 42 in the conventional teaching group. The instruments included a PjBL learning management plan, an online lesson, a learning achievement test, and a satisfaction questionnaire. Data were analyzed using descriptive statistics (means, standard deviations) and inferential statistics (ANOVA and Tamhane's post-hoc test) to identify significant differences between the groups. The findings revealed that students in the online lessons group achieved significantly higher scores than those in the PjBL and conventional teaching groups. Additionally, the PjBL group outperformed the conventional teaching group. Moreover, the participants in both PjBL and Online lessons were satisfied with the instructional methods. The study provides evidence of the comparative effectiveness of online lessons and PjBL for teaching IoT, offering insights to enhance technology-integrated curricula and promote self-regulated learning in 21st-century education.

Keywords: Project-based learning, Online Learning, Internet of Things (IoT)

1. Introduction

It cannot be denied that technology, especially online technology, has become an important part of the new era learning. Since the beginning of the 21st century, the involvement of high-speed internet shift learning paradigm in various aspects (Benchea, 2021; Dettling et al., 2018). To exemplify, learners and teachers have changed the way they interact from the use of telephone calls, email, instance messages, video call, and even in metaverse. This is also a challenge for learners in the 21st century to equip themselves with online technology skills which also include both the skills to use technology in life and learning and digital literacy which allows them to utilize the benefits of the internet with critical mind (Alakrash & Abdul Razak, 2021).

One of the most transformative aspects of online technology is the Internet of Things (IoT)—the idea to allow modern equipment to be integrated with digital connectivity (Kopetz & Steiner, 2022). To be more specify, IoT enables devices such as smart devices, fitness trackers, and even vehicles to collect, share, and act on data through advanced communication networks (Villamil et al., 2020). This can happen by combining sensors, processors, and artificial intelligence. Moreover, IoT applications improve people's real-time decision-making which also allows them to generate automated routine tasks (Laghari et al., 2022). In other words, they could simplify life and make it interconnected. It can be seen that IoT could revolutionize the way human interact with technology; therefore, growing need for individuals to develop both technical proficiency and the critical thinking skills required to navigate and utilize these systems effectively can be notified in a rapidly evolving digital landscape (Ghashim & Arshad, 2023).

In the processes of learning the Internet of Things (IoT), several instructional methods could be utilized to provide learning experiences and necessary skills for students. One of the methods could be encouraging learning through engaging in challenges in student lives by doing a meaningful project as presented in the principles of the project-based learning (PjBL) (Boss & Larmer, 2018; Krajcik & Shin, 2014). According to Roessingh and Chambers

(2011), PjBL encourages students to explore, research, and solve problems collaboratively while building critical thinking, creativity, and practical skills. In developing the learning achievement of the IoT, the method promotes inquiry-based learning, requiring students to search for, analyze, and apply online resources. For example, a project that involves researching internet safety or creating a digital product can give learning by gaining experience with internet tools which leads to the cognitive process that fosters deeper understanding. Therefore, it is potential to integrate PjBL into the curriculum as learners can develop not only content knowledge but also the ability to utilize online technology effectively.

Project-Based Learning (PBL) has been recognized as an effective approach to teaching computer skills, with evidence that indicates the adaptability and relevance of the method to modern technological education. For instance, López-Pimentel et al. (2021) emphasize that PBL can be tailored to technological advancements, making it particularly suitable for teaching complex topics like web programming by integrating sustainability principles and practical project design. Similarly, Malik and Zhu (2023) demonstrate that hands-on activities and flipped teaching, when combined with PBL, enhance students' learning of theoretical computing concepts by promoting active engagement and application of knowledge. Nurbekova et al. (2020) focus on the visualization technologies employed in PBL to teach mobile application development, underscoring the role of interactive tools in improving students' understanding and creativity. Pérez-Rodríguez et al. (2022) take a broader perspective, showing how PBL can integrate challenge-based learning and computer-aided technologies to create a sustainable framework for teaching industrial engineering. Poonputta and Sarnkong (2024) found that PjBL was beneficial in improving the statistical competence and collaborative skills of preservice teachers. Additionally, Shin et al. (2021) highlights the potential of PBL to promote computational thinking by encouraging interdisciplinary and collaborative problem-solving. Together, these studies demonstrate how PBL supports skill development in computer-related fields by providing practical, adaptable, and innovative learning experiences.

Online lessons, on the other hand, can be used as a tool to let learners capitalize the internet's capabilities which deliver content and facilitate self-directed learning to develop their learning achievement of internet learning (Alonso-Mencía et al., 2020). Generally, online lessons often include multimedia resources, interactive activities, and assessments that allow learners to engage with materials at their own pace. Through online lessons, students experience learning by doing, as they navigate educational platforms, participate in virtual discussions, and complete tasks that often require using the internet. Moreover, they can adapt the learning process to their learning style. This form of learning can also nurture independence, as students take ownership of their learning process, exploring and utilizing digital tools to achieve their educational goals.

Online learning and self-regulation have been closely tied according to the evidence. Hwang, Wang, and Lai (2021) argue that incorporating social regulation frameworks into online learning environments significantly enhances students' learning achievements and behaviors, particularly in mathematics. Their study highlights how guided interaction, and collaborative online tasks foster self-regulatory skills among students. Similarly, Jr et al. (2020) emphasizes the importance of self-regulated learning strategies in online environments, noting that effective remote learning depends on students' ability to set goals, monitor progress, and reflect on outcomes independently. Landrum (2020) explores students' confidence in online learning and finds a strong correlation between self-regulation skills and students' perceptions of satisfaction and usefulness in online classes. This study suggests that students who are better at self-regulating tend to engage more effectively and feel more positive about their learning experiences. Furthermore, Viberg, Khalil and Baars (2020) review empirical research on self-regulated learning in online environments and note the potential of learning analytics to support self-regulatory processes, such as tracking learning behaviors and providing feedback to students. It can be said that online learning not only promotes self-regulation, enabling students to take ownership of their learning, but also encourages them to learn by themselves and explore digital tools. By navigating online resources and engaging in self-directed activities, students naturally develop essential skills in using the internet effectively and critically.

Therefore, project-based learning and online lessons seem to have potential in developing learning achievement of internet of things. Comparing the two methods helps us to understand the strengths and limitations of these two instructional methods in teaching skills related to the internet. Although both approaches aim to prepare students for the demands of the 21st century, they differ in structure, student engagement, and the development of skills. Conducting a comparative study can provide an inside perspective into how each improves students' learning achievements. Therefore, it can offer valuable implications for educators seeking to integrate technology into their teaching practices. In this perspective, the current study aims to compare the effects of project-based learning and online lessons on the learning achievement on the internet of things among Thai grade 9 students. The purposes of the study were to compare the effects of project-based learning, online lessons, and conventional teaching on the development of Thai grade 9 students' learning achievement of internet of things and to study the students' satisfaction with project-based learning and online lessons.

2. Research Methodology

2.1 Research Design

The study employed a comparative design utilizing experimental groups and a control Group. Posttest scores of students in each group were compared to justify the results of the study. These key steps were involved—randomly assigning experimental units into two groups, randomly assigning treatments to these groups, conducting the experiment, and then observing or measuring the dependent variables after administering the treatments. Finally, the results are compared between the groups to evaluate the effects of the treatments. Moreover, a satisfactory survey took place to investigate how project-based learning and online lessons satisfy their learning experiences. The research design can be illustrated on the table below.

Table 1. Research design

Sampling	Group	Pre-test	Treatments	Posttest
R	E1	-	PjBL	O
	E2	-	Online lessons	O
	C	-	-	O

2.2 Participants

The participants were 125 Thai Grade 9 Students in a public secondary school in a province in northeastern Thailand. The data collection area was listed in the middle of the socio economy status and national academic ranks (National Institute of Educational Testing Service, 2022; Office of the National Economic and Social Development Council, 2023). The participants were assigned into three groups of an experimental group, one learning with project-based learning (n = 42), an experimental group two (n = 41) learning with online lessons, and a control group (n = 42) learning with a conventional teaching method. The participants were treated considering ethical issues in human research.

2.3 Instruments

2.3.1 Project-Based Learning Management Plan on the Internet of Things (IoT)

Project-based learning is designed and utilized in the current study to promote learning of Internet of Things (IoT) through active activities aiming to let the participants effectively apply their knowledge in daily life or related contexts. On the other hand, online learning is structured to allow them to use technology in learning. This is to provide convenience and enhance learning efficiency. Examples of Learning Activities can be seen below.

In the introduction phase, the teacher presents images or videos about the KidBright board and discusses it with the students. Students are then introduced to an online lesson created by the teacher and directed to the KidBright website. The teacher stimulates students' interest and helps them understand the KidBright website by asking questions such as, "Have you heard of the KidBright board? Do you know what it is and what it does?"

In the teaching phase, students are divided into groups of 4–5 and study a Unit on IoT, focusing on the components of the KidBright board through the online lesson. The teacher demonstrates how to use the KidBright board and guides students in writing a basic program, such as "Automatic Lamp and Fan." Students conduct a project by practicing programming alongside the teacher and explore additional resources from the online lesson. They then complete Worksheet on understanding the components of the KidBright board and present their programming projects via Padlet and the online platform.

In the conclusion phase, the teacher and students summarize the basics of using the KidBright board. Students are assigned to review next week's content via the online lesson. These learning management plans were reviewed for appropriateness by five experts, and the validity of the instructional design was evaluated, yielding a suitability score ranging from 4.40 to 4.80.

2.3.2 Online Lessons for the Internet of Things (IoT)

The online lesson was created using Google Sites for the subject Technology (Computer Science) on the topic of the Internet of Things for Grade 9 students. It consists of one lesson comprising one unit of content. The online lesson was evaluated for its appropriateness by five experts, and its validity was determined, yielding a suitability score ranging from 4.20 to 4.80. This design aims to direct students to learn independently which is also the stimulation of self-regulation in learning. On the other hand, allowing students to explore and engage with the content at their own pace would be the feature that allows online lesson to promote autonomy and the development of critical learning skills as eventually the learning achievement of Internet of Things (IoT).

2.3.3 Internet of Things (IoT) Learning Achievement Test

The Internet of Things (IoT) Learning achievement test was designed as a four multiple-choice test. The item analysis indicates the accepted level of difficulty (p = 0.27–0.88) and discrimination (r = 0.35–0.80). Cronbach's Alpha yields a reliability coefficient of 0.82.

2.3.4 Satisfaction Questionnaire

The student satisfaction questionnaire regarding the learning management on the topic of the Internet of Things using project-based learning and online lessons was designed to have 10 five-Likert scale items. The item analysis indicates the accepted level of validity ($\overline{x}$ = 4.40–4.80), reliability (α = 0.90), discrimination index (r = 0.31–0.67).

2.4 Data Analysis

The participants' post-test comparison was analyzed using One-way ANOVA while the questionnaire results were analyzed by descriptive statistics. The interpretation for questionnaire means scores utilized the criteria of 1.0–1.50 for very low satisfaction, 1.51–2.50 for low satisfaction, 2.51–3.50 for average satisfaction, 3.54–4.50 for high satisfaction, and 4.51–5.00 for very high satisfaction.

3. Results

3.1 The Effects of Project-Based Learning, Online Lessons, and Conventional Teaching on the Development of Thai Grade 9 Students' Learning Achievement of Internet of Things

Table 2. The participants' post-test scores

Methods	**n**	***%***	$\overline{x}$	**S.D.**
PjBL	42	64.29	12.86	2.475
Online lesson	41	72.32	14.46	2.203
Conventional Teaching	42	53.33	10.67	2.270

Table 2 presents the post-test scores of participants across three teaching methods: Project-Based Learning (PjBL), online lessons, and conventional teaching. The PjBL group (n = 42) achieved an average score ($\overline{x}$) of 12.86 (SD = 2.475), with a percentage score of 64.29%. The online lesson group (n = 41) outperformed the others with an average score of 14.46 (SD = 2.203), corresponding to 72.32%. In contrast, the conventional teaching group (n = 42) recorded the lowest average score of 10.67 (SD = 2.270), with a percentage score of 53.33%. These results suggest that online lessons yielded the highest learning achievement among the participants.

Table 3. The comparison between the effects of project-based learning, online lessons, and conventional teaching on the development of Thai grade 9 students' learning achievement of internet of things

Methods		**SS**	**df**	**MS**	**F**	**Sig.**
PjBL	Between groups	301.841	2	150.920	28.039	.000
Online lesson	Within group	656.671	122	5.383		
Conventional Teaching	Total	958.512	124			

Table 3 presents the comparison among participants scores in project-based learning, online lessons, and conventional learning groups. The results of the study indicate a significant difference among the three variables, $F = 28.039, p = 0.00$. The data were further analyzed in a pos-hoc analysis, and the results can be seen below.

Table 4. Pos-hoc analysis on participants' post-test

	Methods		MD	Std. Error	Sig.
Tukey HSD	E1	2	-1.606*	.509	.006
		3	2.190*	.506	.000
	E2	1	1.606*	.509	.006
		3	3.797*	.509	.000
	C	1	-2.190*	.506	.000
		2	-3.797*	.509	.000
Scheffe	E	2	-1.606*	.509	.008
		3	2.190*	.506	.000
	E2	1	1.606*	.509	.008
		3	3.797*	.509	.000
	C	1	-2.190*	.506	.000
		2	-3.797*	.509	.000
Tamhane	E1	2	-1.606*	.514	.007
		3	2.190*	.518	.000
	E2	1	1.606*	.514	.007
		3	3.797*	.491	.000
	C	1	-2.190*	.518	.000
		2	-3.797*	.491	.000

Table 4 shows the results of the post-hoc analysis on participants' post-test scores. Tukey HSD, Scheffé, and Tamhane methods were used to examine whether there are any differences between the variable. It is shown that there are significant differences between the teaching methods at the 0.05 level. In detail, in Tukey HSD, the mean difference (MD) between Project-Based Learning (E1) and Online Lessons (E2) was -1.606 ($p = .006$). The MD between Project-Based Learning (E1) and Conventional Teaching (C) was 2.190 ($p = .000$). Additionally, Online Lessons (E2) outperformed Conventional Teaching (C) with an MD of 3.797 ($p = .000$). Similar patterns were observed in Scheffé and Tamhane methods, confirming the significant differences between the three teaching approaches. These findings highlight the effectiveness of Online Lessons and Project-Based Learning in improving learning outcomes compared to Conventional Teaching.

3.2 The Students' Satisfaction with Project-Based Learning and Online Lessons

Table 5. Participants' satisfaction with project-based learning

No.		$\overline{x}$	S.D.	Interpretation
1	Project-based learning activities are enjoyable and engaging.	4.43	0.63	High
2	Project-based learning activities promote teamwork and collaboration among students.	4.43	0.67	High
3	The content of the projects is connected to daily life.	4.62	0.66	Very high
4	There is sufficient equipment for conducting the projects.	4.33	0.79	High
5	The time allocated for project-based learning activities is appropriate.	4.29	0.77	High
6	Project-based learning activities help develop problem-solving skills.	4.50	0.59	High
7	Project-based learning activities provide opportunities to practice planning and time management for completing projects.	4.26	0.91	High
8	Project-based learning activities receive appropriate guidance and support from teachers.	4.52	0.59	Very high
9	Project-based learning activities incorporate technology into the project process.	4.62	0.62	Very high
10	The activities stimulate creativity in project work.	4.43	0.80	High
Overall		**4.44**	**0.71**	**High**

The satisfaction of Grade 9/9 students with the project-based learning management on the topic of the Internet of Things was rated as high overall ($\overline{x} = 4.44$, S.D. = 0.71). It can be noted that the participants perceived the PjBL learning as an enjoyable instruction that could contribute to collaboration, enhance creativity, and develop problem-solving skills. They also appreciated the relevance of the project content to daily life and the opportunity to use technology in meaningful ways. Additionally, the participants agreed that that PjBL allowed them to practice planning, time management, and teamwork, while receiving appropriate guidance and support from their teacher throughout the process.

Table 6. Participants' satisfaction with online lessons

No.		$\bar{x}$	S.D.	Interpretation
1	The content of the online lessons is interesting, easy to understand, and suitable for students.	4.22	0.85	High
2	The online lessons are easy to access and user-friendly for students.	4.34	0.82	High
3	Activities included in the online lessons effectively promote learning.	4.41	0.84	High
4	The online lessons allow students to learn independently and freely.	4.37	0.70	High
5	The time allocated for each lesson is appropriate.	4.41	0.71	High
6	The menu allows students to choose content to study at their convenience.	4.41	0.77	High
7	The design of the online lessons is visually appealing and engaging.	4.56	0.63	Very high
8	The online lessons offer a variety of learning resources.	4.41	0.81	High
9	Supplementary materials (images, videos) help improve understanding of the content.	4.63	0.66	Very high
10	Activities in the online lessons can be applied by students to create projects.	4.37	0.83	High
Overall		**4.41**	**0.77**	**High**

The results of the study indicate that the satisfaction of the participants with the online lessons on the topic of the Internet of Things was rated as high overall ($\bar{x}$ = 4.41, S.D. = 0.77). It can be noted that the participants in the experimental group 2 perceived the online lessons as an effective and engaging mode of instruction. Additionally, the visually appealing and engaging design of the lessons, along with the flexible menu system that allowed students to select content at their convenience, contributed to their overall satisfaction. The activities included in the online lessons were also highly effective in promoting learning and could be applied by students to create their own projects, adding a practical dimension to their learning experience.

4. Discussion

Therefore, the results of the study could be concluded that participants who learned with online lessons in the experimental group 2 outperformed those in the PjBL group and the conventional teaching group. This could be discussed in relation to the nature of the learning achievement topic, which is the Internet of Things. It's a topic closely tied to daily life, and students in this era, belonging to Gen Z and Alpha, were born into a world immersed in technology. They are naturally familiar with these concepts and tools. Giving them projects in PjBL might limit their independence, while lecture-based conventional teaching lacks the hands-on experience needed for such a practical subject. Therefore, it may be more effective to allow them to learn independently through online courses in this context.

This approach aligns well with the self-regulated nature of online learning, enabling students to take ownership of their learning process, explore content at their own pace, and engage with diverse resources that resonate with their technological upbringing. In this study, the design of the online lessons, with interactive activities, visually appealing materials, and accessible tools, supported these self-regulated learning behaviors, making it a particularly effective approach for teaching concepts related to the Internet of Things. The results of the study went in line with previous studies (Jr et al., 2020; Landrum, 2020; Viberg et al., 2020) who also tide self-regulation contributed by online learning and the development of computer-related skills.

Moreover, it could also be noted that the participants in the experimental group 1, who learned with PjBL, outperformed those in the conventional learning group. This finding highlights the advantages of PjBL over traditional lecture-based instruction, particularly in fostering active engagement, critical thinking, and collaboration. Comparatively, in lecture-based learning, students often get involved in passive knowledge reception. Meanwhile, PjBL allows students to work on real-world projects as exemplified by the learning of KidBright website in this study. This interactive and student-centered approach makes learning more meaningful and contributes to the development of essential 21st-century skills, such as problem-solving, teamwork, and time management.

The results of this study are consistent with those of prior research (e.g., Hwang et al., 2021; López-Pimentel et al., 2021; Malik & Zhu, 2023; Nurbekova et al., 2020; Pérez-Rodríguez et al., 2022; Shin et al., 2021) who also found the benefit of PjBL in computer education. For example, Nurbekova et al. (2020) reported that PjBL effectively improves creativity and practical skills in mobile application development, and Pérez-Rodríguez et al. (2022) illustrated its relevance in integrating computer-aided technologies for industrial engineering education. Finally, Shin et al. (2021) found that PjBL promotes computational thinking by engaging students in interdisciplinary and collaborative tasks.

These findings collectively reinforce the value of PjBL as a superior instructional method for teaching computer-related topics, including the Internet of Things, by combining active learning, collaboration, and practical skill development.

5. Conclusion

The study aimed to compare the effects of project-based learning (PjBL) and online lessons on Thai Grade 9 students' learning achievement on the Internet of Things (IoT). A control group receiving conventional instruction was also included. The results indicated that students in the online lessons group outperformed those in both the PjBL and conventional teaching groups. This discovery indicates that online classes might be especially beneficial for instructing IoT concepts, likely because of the self-guided and technology-oriented essence of online education, which aligns closely with Generation Z and Alpha learners who are naturally accustomed to digital technologies.

The research adds to the domain by presenting comparative data on the effectiveness of various teaching techniques in computer education. The results suggest that integrating online classes can improve the instruction of computer-related topics by utilizing students' current technological knowledge and encouraging self-directed learning. For policymakers, this highlights the necessity of incorporating technology skills into 21st-century education to better match students' learning styles and the changing digital environment.

Nonetheless, the research has drawbacks, such as lacking qualitative data and having a limited sample size. Future studies ought to include qualitative assessments to attain a better understanding of students' learning experiences and increase the sample size to enhance the generalizability of the results. Moreover, contrasting PjBL with other recognized methods in computer education, like game-based learning and intelligent tutoring systems, would offer a broader insight into effective teaching techniques in this field.

Acknowledgments

Not applicable.

Authors' contributions

Not applicable.

Funding

Not applicable.

Competing interests

Not applicable.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

References

Alakrash, H. M., & Abdul Razak, N. (2021). Technology-Based Language Learning: Investigation of Digital Technology and Digital Literacy. *Sustainability*, *13*(21), Article 21. https://doi.org/10.3390/su132112304

Alonso-Mencía, M. E., Alario-Hoyos, C., Maldonado-Mahauad, J., Estévez-Ayres, I., Pérez-Sanagustín, M., & Delgado Kloos, C. (2020). Self-regulated learning in MOOCs: Lessons learned from a literature review. *Educational Review*, *72*(3), 319–345. https://doi.org/10.1080/00131911.2019.1566208

Benchea, L. (2021). Analysis on the Relationship Between Internet Use and Students' Academic Engagement. *Journal of e-Learning and Higher Education*, *23*, 112–122. https://doi.org/10.5171/2021.237803

Boss, S., & Larmer, J. (2018). *Project Based Teaching: How to Create Rigorous and Engaging Learning*

Experiences. ASCD.

Dettling, L. J., Goodman, S., & Smith, J. (2018). Every Little Bit Counts: The Impact of High-Speed Internet on the Transition to College. *The Review of Economics and Statistics*, *100*(2), 260–273. https://doi.org/10.1162/REST_a_00712

Ghashim, I. A., & Arshad, M. (2023). Internet of Things (IoT)-Based Teaching and Learning: Modern Trends and Open Challenges. *Sustainability*, *15*(21), Article 21. https://doi.org/10.3390/su152115656

Hwang, G.-J., Wang, S.-Y., & Lai, C.-L. (2021). Effects of a social regulation-based online learning framework on students' learning achievements and behaviors in mathematics. *Computers & Education*, *160*, 104031. https://doi.org/10.1016/j.compedu.2020.104031

Jr, R. A. C., Rice, M., Yang, S., & Jackson, H. A. (2020). Self-regulated learning in online learning environments: Strategies for remote learning. *Information and Learning Sciences*, *121*(5/6), 321–329. https://doi.org/10.1108/ILS-04-2020-0114

Kopetz, H., & Steiner, W. (2022). Internet of Things. In H. Kopetz & W. Steiner (Eds.), *Real-Time Systems: Design Principles for Distributed Embedded Applications* (pp. 325–341). Springer International Publishing. https://doi.org/10.1007/978-3-031-11992-7_13

Krajcik, J. S., & Shin, N. (2014). Project-Based Learning. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (2nd ed., pp. 275–297). Cambridge University Press. https://doi.org/10.1017/CBO9781139519526.018

Laghari, A. A., Wu, K., Laghari, R. A., Ali, M., & Khan, A. A. (2022). A Review and State of Art of Internet of Things (IoT). *Archives of Computational Methods in Engineering*, *29*(3), 1395–1413. https://doi.org/10.1007/s11831-021-09622-6

Landrum, B. (2020). Examining Students' Confidence to Learn Online, Self-Regulation Skills and Perceptions of Satisfaction and Usefulness of Online Classes. *Online Learning*, *24*(3), 128–146. https://doi.org/10.24059/olj.v24i3.2066

López-Pimentel, J. C., Medina-Santiago, A., Alcaraz-Rivera, M., & Del-Valle-Soto, C. (2021). Sustainable Project-Based Learning Methodology Adaptable to Technological Advances for Web Programming. *Sustainability*, *13*(15), Article 15. https://doi.org/10.3390/su13158482

Malik, K. M., & Zhu, M. (2023). Do project-based learning, hands-on activities, and flipped teaching enhance student's learning of introductory theoretical computing classes? *Education and Information Technologies*, *28*(3), 3581–3604. https://doi.org/10.1007/s10639-022-11350-8

National Institute of Educational Testing Service. (2022). *ONET result 2023*. Retrieved from https://www.niets.or.th/th/content/view/11821

Nurbekova, Z., Grinshkun, V., Aimicheva, G., Nurbekov, B., & Tuenbaeva, K. (2020). Project-Based Learning Approach for Teaching Mobile Application Development Using Visualization Technology. *International Journal of Emerging Technologies in Learning* (iJET), *15*(8), 130–143. https://doi.org/10.3991/ijet.v15i08.12335

Office of the National Economic and Social Development Council. (2023). *Gross Regional and Provincial Product Chain Volume Measures 2022 Edition*. Retrieved from https://lookerstudio.google.com/u/0/reporting/704fe6c7-aecb-4362-9062-3dc971c75982/page/p_woqsppkotc

Pérez-Rodríguez, R., Lorenzo-Martin, R., Trinchet-Varela, C. A., Simeón-Monet, R. E., Miranda, J., Cortés, D., & Molina, A. (2022). Integrating Challenge-Based-Learning, Project-Based-Learning, and Computer-Aided Technologies into Industrial Engineering Teaching: Towards a Sustainable Development Framework. *Integration of Education*, *26*(2), 198–215. https://doi.org/10.15507/1991-9468.107.026.202202.198-215

Poonputta, A., & Sarnkong, R. (2024). Improving the statistical competence and collaborative skills of preservice teachers through learning by teaching and project-based learning. *International Journal of Innovative Research and Scientific Studies*, *7*(4), 1542–1550. https://doi.org/10.53894/ijirss.v7i4.3453

Roessingh, H., & Chambers, W. (2011). Project-Based Learning and Pedagogy in Teacher Preparation: Staking out the Theoretical Mid-Ground. *International Journal of Teaching and Learning in Higher Education*, *23*(1), 60–71.

Shin, N., Bowers, J., Krajcik, J., & Damelin, D. (2021). Promoting computational thinking through project-based learning. *Disciplinary and Interdisciplinary Science Education Research*, *3*(1), 7. https://doi.org/10.1186/s43031-021-00033-y

Viberg, O., Khalil, M., & Baars, M. (2020). *Self-regulated learning and learning analytics in online learning environments: A review of empirical research* (pp. 524–533). Proceedings of the Tenth International Conference on Learning Analytics & Knowledge. https://doi.org/10.1145/3375462.3375483

Villamil, S., Hernandez, C., & Tarazona, G. (2020). An overview of internet of things. *Telecommunication Computing Electronics and Control*, *18*(5), Article 5. https://doi.org/10.12928/telkomnika.v18i5.15911

Copyrights