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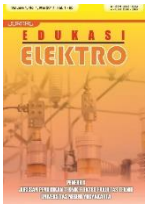

Ubiquitous Learning with Online Project-Scratch Programming: Enhancing Student Engagement and Developing Problem-Solving Skills

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Abstract— Low student engagement in online learning is a challenge faced by many educators. The choice of tools used in online learning is also critical in determining whether they support ubiquitous learning for students. One tool that has proven effective in traditional (classroom) learning to increase engagement and problem-solving skills is Problem-Based Learning (PBL) on the Scratch platform. The purpose of this study is to examine whether PBL-Scratch can increase student engagement and perceptions of problem-solving skills in online learning. The study uses a quasi-experimental approach with a simple t-test analysis. The results indicate that PBL-Scratch can increase student engagement with a significance of 0.008 and perceived problem-solving skills in online learning with a significance of 0.025, making it a viable tool for ubiquitous learning.

Keywords: engagement, problem-solving skills, scratch, problem-based learning, ubiquitous learning.

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1 Introduction

In today's digital age, technological advancements have transformed many aspects of life, including education. Technology enables students to learn anytime and anywhere, a concept known as ubiquitous learning [1]. This concept brings significant changes to the learning process, where spatial and temporal limitations no longer prevent students from accessing different learning resources. With ubiquitous learning, the learning process becomes more flexible [2] and adaptive to individual needs.

One challenge in this era, however, is ensuring that every student has strong problem-solving skills [3]. These skills are critical as the complexity of real-world problems continues to increase. Students are expected not only to understand the material, but also to apply it in different contexts, which requires well-developed critical thinking and problem-solving skills.

Project-based learning is a highly relevant approach in this context, as it allows students to engage directly in practical and applied learning processes [4]. By involving students in real-world projects, they not only learn theory, but also apply their knowledge to solve real-world problems. This approach encourages collaboration among students, improves communication skills, and facilitates deeper learning. In addition, project-based learning can increase student motivation [5], [6], as they

see tangible results from their efforts, creating a more meaningful and enjoyable learning experience [7].

In order to develop problem-solving skills in the context of ubiquitous learning, appropriate learning media are essential [8]. These media should allow students to explore different situations and problems and provide space to develop critical and creative thinking skills. One promising tool is online Scratch programming, which can be used to teach problem solving through interactive programming [9].

Nevertheless, online learning has its challenges, especially in terms of low student engagement [10]. Online learning often depends on students' self-motivation, which, if not well managed, can lead to a lack of active participation [11] and ultimately affect learning outcomes. Therefore, it is important to design a learning model that not only effectively develops problem-solving skills, but also significantly enhances student engagement.

This study aims to propose an appropriate learning model in the context of ubiquitous learning using online Scratch programming. The model is expected to enhance students' problem-solving skills while increasing students' engagement in online learning. Thus, the results of this study are expected to contribute significantly to the development of learning methods in an increasingly complex digital era.

With this in mind, this study formulates two research questions:

1. Does Scratch programming increase student engagement in online learning?
2. Does project-based Scratch learning improve students' perceptions of their problem-solving skills?

2 Literature review

2.1 Ubiquitous Learning tools

Ubiquitous learning tools have become a key area of research in modern education, especially with technological advancements that allow unlimited access to information. These tools are designed to support learning anytime, anywhere, and provide students with the flexibility to learn at their own pace [12]. They include not only educational applications, but also mobile devices, online platforms, and other easily accessible digital resources. These tools allow students to engage in more personalized and contextualized learning experiences, increasing their relevance and motivation to learn.

In addition, previous studies indicate that the use of widely accessible learning tools promotes collaboration and interaction among students [13], which are essential components of 21st century learning. By leveraging existing technology, students can participate in discussions, share resources, and collaborate on projects from different locations. This is consistent with the principles of project-based learning (PBL) [14], in which students engage in solving real-world problems with the support of digital tools that facilitate communication and collaboration. Thus, the use of ubiquitous learning tools positively impacts students' social and problem-solving skills.

2.2 Writing Drone Simulator - PBL and Problem-Solving Skills

The use of drone simulation as a project-based learning (PBL) tool has been shown to be effective in improving students' problem-solving skills [15]. Drone simulation in education allows students to explore real-world scenarios and learn through hands-on experience. In PBL, students face challenges that require them to design, test, and evaluate their solutions, which promotes critical thinking and analytical skills [16]. The simulation educates students about drone technology and helps them understand the mathematical and scientific concepts involved in drone operations.

In addition, previous research has shown that PBL integrating drone technology can increase students' motivation and engagement, which can positively impact their problem-solving skills [17]. By providing a space for students to work collaboratively on challenges, they learn to support each other and share ideas, which is critical to the learning process. This approach creates a dynamic

learning environment where students learn from the instructor and each other, resulting in a richer and more meaningful learning experience.

2.3 Scratch Programming and Student Engagement

Scratch programming has become an effective tool for increasing student engagement, especially in project-based learning (PBL) contexts (Marcelino et al., 2018; P. Rose et al., 2020). Scratch is designed to help students create multimedia projects in a fun and interactive way. Through Scratch, students can learn about programming logic, algorithms, and problem solving while creating games, animations, or interactive stories (Tan et al., 2021). Research shows that student engagement increases significantly when students express their creativity through self-designed projects in Scratch.

In addition, previous studies highlight that Scratch increases student engagement and fosters collaboration and communication skills when students work in groups (Dúo-Terrón, 2023). Students learning with Scratch tend to be more active in discussions, sharing ideas and providing feedback to their peers. This is consistent with the principles of PBL, in which students are encouraged to collaborate and solve real-world problems (Elzomor et al., 2018). Thus, Scratch programming combines digital learning tools with PBL approaches to create a more engaging and hands-on learning experience for students in the digital age.

3 Methodology

This study uses an online quasi-experimental design with experimental and control groups. Activities for both groups were conducted online over three sessions of four hours each. The participants in this research, including the experimental group, comprised 38 students, while the control group consisted of 41 students. This count of the sample is the total number of students in each class, which means we used 2 class regular classes. The study was conducted at the university level, and the participants were freshmen studying basic computation. The sample consisted of 68 male and 11 female students.

Table 1. Quasi-experimental activities

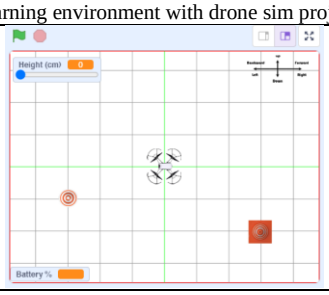
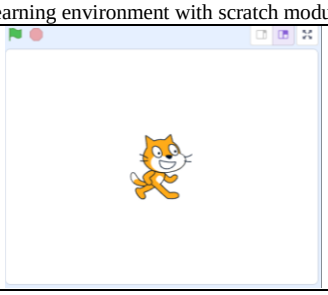
Experimental Group (Online Class)		Control Group (Online Class)	
20"	Introduction to Learning	20"	Introduction to Learning
15"	Pre-test	15"	Pre-test
100"	Scratch Programming with Initial Guidance	100"	Scratch Programming with Initial Guidance
50"	Independent Practice	50"	Independent Practice
100"	Introduction to Drone Simulator Programming with Scratch	100"	Introduction to Scratch Programming with Default Story (Cat Story)
100"	Independent Practice with Drone Simulator Development using Scratch	100"	Independent Practice Developing Cat Story
50"	Demonstration of Drone Simulator Creation Results	50"	Demonstration of Cat Story Creation Results
15"	Post-test	15"	Post-test
Learning environment with drone sim project		Learning environment with scratch module	
			

Table 1 outlines the research activities conducted using a quasi-experimental approach. Both groups participated in Scratch programming activities online (from their respective homes/locations). The difference was in the programming topic: the experimental group worked with a drone simulator, while the control group focused on cat movement (the default Scratch object/sprite). The drone simulator learning activity presented real-world challenges such as direction, distance, and position, while the cat movement task only presented direction and movement step challenges. Indirectly, the drone simulation introduced more complex problems to observe its impact on students in the experimental group.

In the control class, students learn how to program the movement of a cat. The cat's movement is limited to moving forward or backward, advancing, or turning around. Meanwhile, in the experimental class, students learn how to control a drone's movement from a top-view perspective. The movements include takeoff, landing, moving forward, backward, sliding to the right, sliding to the left, and measuring the distance traveled. These two distinct aspects differentiate the control class from the experimental class.

The study measured student factors using two published instruments: Engagement [18] and the Problem-Solving Inventory [19]. Each instrument demonstrated strong reliability, with Cronbach's alpha values of 0.82 for engagement and 0.88 for the problem-solving inventory.

4 Result and Discussion

4.1 Improving Student Engagement in Online Learning

Online learning is often under scrutiny due to the challenges of keeping students focused and fully engaged during the learning process [10]. Unlike face-to-face learning, where instructors can easily monitor and direct student attention through direct interaction-both among students and between students and instructors-online learning lacks this level of control. As a result, many students feel less engaged or experience low levels of engagement due to the lack of direct interaction and adequate supervision [10]. This challenge is further exacerbated by potential distractions from the home environment or unstable Internet access, which can make it easier for students to lose focus.

However, several strategies can be implemented to increase student engagement in online learning, including interactive learning platforms such as Scratch [9]. Scratch is a visual programming platform designed to teach students basic programming concepts in a fun and accessible way [20]. By using Scratch, students can engage in more engaging learning activities that increase their participation and allow them to learn independently and creatively. The platform offers a range of tools and features that allow students to create and collaborate on online projects, reintroducing the element of interaction that is often missing from online learning. Therefore, using platforms such as Scratch can effectively increase student engagement and ensure that the online learning process runs more smoothly.

Table 2. T-test analysis of student engagement

Paired Samples Test (Engagement)

class		*Mean*	*N*	*Std. Deviation*	*Paired Differences*			*t*	*df*	*Sig. (2-tailed)*
					Mean	Std. Dev	Std. Err. Mean			
Exp. Class	Pre	3.808	38	0.280	-0.120	0.266	0.043	-2.796	37	0.008
	Post	3.928	38	0.289						
Con. Class	Pre	3.753	41	0.355	-0.124	0.355	0.055	-2.235	40	0.031
	Post	3.877	41	0.372						

Based on the data in Table 1, a paired samples t-test was conducted to measure the change in engagement scores before and after the intervention in two groups: the experimental and control classes. In the experimental class, the mean engagement score increased from 3.808 before the intervention to 3.928 after the intervention. This difference in means is -0.120, with a standard

deviation of 0.266, and the t-test result shows a t-value of -2.796 with 37 degrees of freedom (df), which is significant at the 0.008 level. Meanwhile, the average engagement score in the control class increased from 3.753 to 3.877. The difference in means here is -0.124 with a standard deviation of 0.355 and a t-value of -2.235 with 40 df, significant at the 0.031 level.

The results of the analysis in Table 2 indicate a significant increase in engagement levels in both classes, experimental and control. In the experimental class, this increase is slightly smaller in absolute terms than in the control class, but remains statistically significant. This suggests that the intervention applied in the experimental class had a positive effect on student engagement, although the increase was not very different from that in the control class. The statistical significance at the 0.008 level indicates that these results are unlikely to be due to chance and that the intervention can be considered effective in increasing engagement.

On the other hand, the significant increase in the control class also suggests that other factors may have contributed to the increase in student engagement. These may include external variables such as changes in general teaching methods or other motivational factors unrelated to the intervention. Thus, while the intervention appears to be appropriate, it is important to consider additional factors that may have influenced the results.

4.2 Improving Perceptions of Problem-Solving Skills

The skills students need today are part of the 21st century competencies, which include several essential aspects to prepare them for future challenges. One critical skill required is problem solving [21]. This skill is crucial because it enables students to think critically, analyze situations, and find effective solutions to the various problems they encounter. In an ever-changing world, the ability to solve problems becomes one of the keys to success in various aspects of life.

Problem solving skills can be developed through various teaching methods, including project-based or problem-based learning [22]. This method allows students to directly engage in a more practical and applicable learning process, where they can identify real-world problems and seek solutions independently or in groups. In this study, the learning scenario adopted is project-based learning, which is conducted online. This method enhances students' problem-solving skills and prepares them to work collaboratively and creatively in a digital environment. The following table presents the results of the experiment using online project-based learning, which shows a significant improvement in students' skills.

Table 3. T-test analysis of student problem-solving

Paired Samples Test (Problem-Solving)

class		*Mean*	*N*	*Std. Deviation*	*Paired Differences*			*t*	*df*	*Sig. (2-tailed)*
					Mean	Std. Dev.	Std. Err. Mean			
Exp. Class	Pre	4.334	38	0.316	-0.109	0.287	0.047	-2.330	37	0.025
	Post	4.442	38	0.403						
Con. Class	Pre	4.092	41	0.472	-0.002	0.012	0.002	-0.813	40	0.421
	Post	4.094	41	0.469						

Table 3 presents the results of the paired samples t-test conducted to measure changes in problem solving skills before and after the intervention in the experimental and control classes. In the experimental class, the average problem-solving score increased from 4.334 before the intervention to 4.442 after the intervention. The mean difference was -0.109 with a standard deviation of 0.287, and the t-test result showed a t-value of -2.330 with 37 degrees of freedom (df), which was significant at the 0.025 level. In contrast, the control class showed a negligible change in problem solving score from 4.092 to 4.094. The mean difference was -0.002 with a standard deviation of 0.012, and the t-value was -0.813 with 40 df, which was not significant at the 0.421 level.

The analysis indicates a significant improvement in problem solving skills in the experimental class after the intervention, while the control class showed no significant change. The significant

increase in the experimental class indicates that the applied intervention effectively improved students' problem-solving skills. The significance value of 0.025 indicates that this result is unlikely to have occurred by chance, confirming the success of the intervention in this context.

Conversely, the results from the control class show no significant change in problem-solving skills, indicating that students' skills remained stable without the intervention. This underscores the tangible and positive impact of the intervention used in the experimental classroom. It is important to recognize that other unmeasured factors may have contributed to these results; however, the data suggest that the intervention was the primary factor in improving problem-solving skills in the experimental class.

The overall analysis indicates that the intervention implemented in the experimental class had a significant positive impact on student engagement and problem-solving skills. Although the increase in student engagement in the experimental class was smaller in absolute terms than in the control class, its statistical significance indicates that the intervention was effective. Conversely, the significant improvement in student engagement in the control class suggests that other external factors may have contributed to this outcome.

In terms of problem-solving skills, the intervention proved successful and significant in the experimental class, while the control class showed no significant changes. This reinforces the role of the intervention, which explicitly uses a simulator on the Scratch platform, as the primary factor in improving problem-solving skills.

The results of this study are consistent with previous research showing that problem-based learning (PBL) integrated with Scratch can effectively increase student engagement [23], [24], [25] and perceptions of problem-solving abilities [20], [26], [27], [28], [29], [30]. This is especially true when Scratch is used in an online learning environment as a tool for ubiquitous learning. Overall, the findings confirm the potential of integrating technology and innovative pedagogical approaches to improve educational outcomes in terms of student engagement and problem-solving skills.

5 Conclusion

The results of this study show that the project-based learning intervention had a significant impact on student engagement and problem-solving skills in the experimental classroom. While there was an increase in engagement in the control class, the analysis indicated that the intervention was more effective in increasing student engagement in the experimental class. The experimental class also significantly increased students' problem-solving skills, while the control class showed no meaningful changes. These results highlight the importance of active learning methods in improving students' skills, especially through problem-based learning using the Scratch platform in online education.

6 Future Suggestion

For future research, it is recommended that the specific elements of project-based learning interventions that are most effective in improving student engagement and problem-solving skills be explored. Studies could include several variables, such as instructional methods, types of projects, and interactions among students. In addition, conducting longitudinal studies may provide insight into the long-term effects of such interventions on students' skills. The use of a more diverse control group and the consideration of external factors will also be crucial for a more comprehensive understanding of the dynamics of learning in online contexts

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