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Interactive Cell Model Creation: Exploring High School Students' Engagement in Understanding Cell Concepts through *Scratch Coding-Based Project-Based Learning (PBL)*

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Abstract

This study aims to analyze the effectiveness of implementing Project-Based Learning (PBL) with Scratch Coding in increasing high school students' interest and skills regarding the biological concept of the cell. The descriptive qualitative method was used with subjects from Grade XI at SMA Negeri 1 Bancar. Data were collected through interest questionnaires (pre- and post-intervention), observations, interviews, and coding product assessments. The results indicate a significant increase in learning interest, exceeding 20% across all indicators-anthusiasm, motivation, and perceived difficulty. Gamification elements in Scratch contributed to this improvement, allowing students to engage more deeply with interactive cell model creation. Students demonstrated the ability to integrate conceptual understanding with computational thinking skills, reflected in high product rubric scores. This research recommends PBL Scratch Coding as an innovative and effective approach for learning cell biology through creative and game-based experiences.

Keywords: Project-Based Learning (PBL), Scratch Coding, Learning Interest, Cell Concept, Computational Skills.

1. INTRODUCTION

A deep understanding of the cell concept is a critical foundation in High School Biology, given that the cell is a complex and abstract fundamental unit of life. Traditional learning that relies solely on static two-dimensional (2D) images often fails to bridge the gap between visual representation and the actual functional complexity of the cell. This situation causes students to find it difficult to visualize the dynamics of organelles and other vital processes, leading to a decrease in students' cognitive engagement.

Previous research concluded that the use of visual literacy-based learning media influences high school students' Biology learning outcomes. By utilizing the visualization of complex biological concepts, this learning media can help students understand the

material better, increase information retention, and enhance student engagement in the learning process (Reski & Muhyiatul, 2025).

The use of digital technology in the teaching and learning process in the 21st century has had a significant impact on students' creativity, changing the way they think, learn, and produce work. Digital technology provides tools and platforms that allow students to explore their ideas more freely and innovatively. In the context of learning, this technology enables students to adapt to activities that demand creative thinking and out-of-the-box solutions (Suyato et al, 2023). Teachers in the 21st century play a crucial role in shaping students who are not only digitally smart but also ready to face an increasingly complex and connected future (Afifah, 2024).

Facing these challenges, the integration of computational technology becomes a relevant solution. The Project-Based Learning (PBL) framework offers an ideal environment where students can build their understanding deeply through authentic and challenging projects (Thomas, 2000). In this context, the use of the Scratch platform, an intuitive block-based visual coding environment, allows high school students to create an Interactive Cell Model. Scratch's advantage lies in its ability to teach programming concepts without complex syntax barriers, thus keeping students' focus on content and interactive model design (Resnick et al, 2009). The interactivity feature in Scratch allows students to actively engage in material exploration, thereby facilitating student-centered learning. The gamification approach in Scratch can increase students' motivation and engagement in learning (Hidayah et al, 2024).

The process of coding this cell model is not merely creating an animation ; it compels students to actively solve problems, design algorithms that replicate cell functions, and explicitly define the structural-functional relationships of the cell. Therefore, this research aims to deeply explore the engagement of high school students and the effectiveness of their understanding of cell concepts through the implementation of PBL Scratch Coding in creating the Interactive Cell Model. The main focus of this article is on the interactive and creative dimensions of technology-facilitated learning, particularly in enhancing conceptual understanding that has previously been difficult to achieve. The contribution of this research is expected to provide a practical model for Biology educators at the high school level, demonstrating how the integration of coding and PBL can transform abstract material into a concrete, meaningful experience that aligns with the vision of the modern curriculum.

2. RESEARCH METHODE

This research uses a Descriptive Qualitative approach which aims to deeply understand the phenomena, context, and processes occurring during the implementation of Project-Based Learning (PBL) Scratch Coding in cell concept learning, as well as to describe student engagement and changes in interest. Moleong, L. J., (2021) states that qualitative research is a research method that produces descriptive data in the form of written or spoken words obtained from people and observable behavior. This research was conducted at SMA Negeri 1 Bancar with the Research Subjects being Class XI students who were currently studying Biology material on the Cell concept. The selection of subjects was based on the need to intensively understand the learning process and outcomes of students at this level.

Research data was obtained using several techniques to achieve specific research objectives, especially describing the success of increasing interest (through "playing games") and measuring applied coding skills, namely Structured Participatory Observation: focusing on systematically observing and recording the level of student engagement, interaction, and expression of interest (affective) during the PBL process (starting from planning, coding, to model testing) and the instrument used was an Observation Sheet containing key indicators such as initiative in coding, team collaboration, duration of focus, expression of excitement when testing the interactive game, and questions asked related to cell concepts/code; the next technique is In-depth Interview (Semi-Structured): focusing on exploring students' perceptions, motivation, and reflection on the PBL Scratch Coding learning method; the third technique is Performance Assessment and Product Analysis, which focuses on measuring students' technical skills (coding) and conceptual understanding realized in their final project, the instrument being a Rubric; the fourth technique is the Learning Interest Questionnaire (Pre- and Post-Intervention) focusing on more measurably assessing the change in students' affective (interest) towards cell biology material. Field test results show that the SCRATCH learning media is effective in increasing students' understanding of the food chain concept. This is indicated by an increase in the average score from 67.3 on the pretest to 88.5 on the posttest, with an N-gain value of 0.65 which is categorized as "moderate". The percentage of learning completeness also increased significantly from 54.2% on the pretest to 91.7% on the posttest (Yuniarto, 2025).

This research will describe three main aspects: Student Engagement Process: Describing how students interact with the project (creating an interactive cell model using Scratch); Change in Interest and Perception: describing the level of student interest in cell material before and after the intervention (with a focus on the "playing games" element); and Technical and Conceptual Skills: Measuring and describing students' ability to apply Scratch coding to represent complex cell biology concepts

3. RESULTS AND DISCUSSION

The data obtained from the implementation of Project-Based Learning (PBL) Scratch Coding focuses on increasing student interest and measuring their skills in applying coding to cell concepts.

3.1 Research Results Increase in Student Learning Interest (Affective Aspect)

Data shows a significant increase in students' learning interest in cell Biology material after the implementation of PBL Scratch Coding, supported by the Interest Questionnaire and In-depth Interviews**.**

- **Learning Interest Questionnaire Results**

Interest Indicator (Indikator Minat)	Pre-Intervention (Average Score)	Post-Intervention (Average Score)	Increase (%)
Enthusiasm and Engagement	65,2	88,9	+23,7%
Perception of Material Difficulty	58,1	85,5	+27,4%
Independent Learning Motivation	62,5	87,2	+24,7%

- **In-depth Interview Findings (Exploring the Game Element)**

  Interviews confirmed that the interactive and game-based element was the main trigger for the increase in interest.
  "Initially, the cell was just a picture in a book, boring. But because we had to make the cell move, function, and be able to interact in Scratch (like a game), learning became fun and addictive. We could test drive our own created cell." (Student A)

"The most exciting part was testing the code. If there was a bug, it felt like having to win a game level to fix it. This made Cell Biology feel more real and applicable." (Student C)

2. Students' Skills in the Coding Creation Process (Cognitive and Psychomotor Aspects)

Measurement was done through the Project Assessment Rubric and Final Product Analysis to assess students' ability to integrate cell concepts into the Scratch code.

Skill Aspect (Aspek Keterampilan)	Assessment Criteria (Kriteria Penilaian)	Group Average Score (Scale 1-4)
Conceptual Accuracy	Accuracy of representing cell organelle functions (e.g., simulation of energy transfer by mitochondria)	3,4
Scratch Coding Skill	Code efficiency, use of complex and functional variables/loops/conditions (if-then)	3,2
Product Interactivity	Ability of the game/simulation to respond to user input (e.g., click to view organelle function)	3,6

3.2 DISCUSSION

The research results strongly support the hypothesis that the PBL method integrated with coding (PBL Scratch Coding) successfully increased the learning interest of Class XI students at SMA Negeri 1 Bancar. Relevance and Concretization: PBL Coding changed cell learning from the abstract realm to the concrete and meaningful (Abidin, 2018). Students did not just memorize, but created a cell model that was alive and playable. Gamification Effect; The element of interaction, testing (debugging), and achievement inherent in Scratch coding functions as a gamification mechanism. This aligns with the theory stating that the control (*autonomy*) and competence gained by students when mastering coding drive intrinsic motivation and sustained interest.

The success of the research is not only in the aspect of interest but also in the measurement of students' integral skills. Coding Skills as a Tool for Understanding are

shown by high scores on the Conceptual Accuracy aspect (3.5) and Coding Skills (3.2), indicating that students were able to use complex Scratch syntax (*if/then*, *loop*, *broadcast*) to model specific biological processes. For example, to simulate the osmosis mechanism, students had to use variables and mathematical operators in their code, which proves a deep understanding of the concept. 21st Century Skills: This PBL process effectively trains computational thinking skills (problem decomposition, pattern recognition, abstraction) which are demands of the 21st century. Students who initially had no coding background successfully applied algorithms to cell material, which shows that Scratch is an effective and easily accessible tool for interdisciplinary teaching. The interview results also indicate that students were more interested and enthusiastic about learning cell concepts using the technique of creating a game about plant cells with Scratch coding; the cell image was able to talk about the function of each cell part. PBL Scratch Coding has great potential to create a learning environment that not only enhances understanding but also cultivates students' intrinsic interest by making the learning process like a process of playing and creating games.

4. CONCLUSION

Based on the analysis of descriptive qualitative data from observations, in-depth interviews, product analysis, and quantitative data from the questionnaire, this research concludes that the implementation of the Project-Based Learning (PBL) Scratch Coding method is effective in increasing the learning interest of Class XI students at SMA Negeri 1 Bancar towards the cell concept material.

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