

Exploring Cross-Disciplinary Education: Enhancing Science Learning with Digital Picture Books

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Abstract: The research developed a digital picture book titled "My Helpful Friend: Hydrogen" on hydrogen energy. Collaborative efforts across disciplines led to the successful creation of the picture book, which was then tested with the participation of 11 first-year college students. The findings indicate that incorporating digital picture books into science education improves student learning outcomes and encourages a positive attitude toward learning. In addition to offering empirical evidence, the study presents practical tools and techniques for cross-disciplinary learning. Future research endeavors could explore diverse themes and subjects to further enhance students' learning experiences and promote the development of creativity and collaborative skills for addressing real-world challenges.

Keywords: Cross-disciplinary learning, Digital picture book, Hydrogen energy, Science Education

1. Research Background

Digital technologies have revolutionized science education by offering innovative teaching methods such as animation, short films, augmented reality, and virtual reality. Moreover, Yakman and Maeda, prominent American scholars, advocate for the integration of arts into science education, leading to the establishment of the STEM to STEAM framework (Maeda, 2013; Yakman, 2010). STEAM's evolving educational paradigm prioritizes interdisciplinary research, design thinking, and practical problem-solving skills (Hardiman, 2016). It recognizes the significance of inquiry-based learning and abilities applicable to real-life educational contexts. By amalgamating these principles, science education strives for a more comprehensive approach to nurture students' interdisciplinary capabilities and effectively

empower them to address real-world challenges. This study underscores the importance of cross-disciplinary curricula with increased depth and practical application value.

2. Research Motivation

The primary aim is to advance energy education, specifically focusing on hydrogen energy issues. This research's central objective is creating the digital picture book "My Helpful Friend: Hydrogen," which revolves around the theme of hydrogen energy. The goal is to aid students interested in hydrogen energy but lacking a comprehensive understanding.

By engaging with "My Helpful Friend: Hydrogen," the researchers seek to expand students' awareness of hydrogen energy. Picture books are chosen as the primary instructional tool due to their cohesive visual style and narrative depth. Augmented Reality (AR) and Virtual Reality (VR) are supplementary tools to enrich students' understanding and enthusiasm for hydrogen energy. This teaching approach encourages students to contemplate energy issues and ponder the intricate relationship between humanity and the Earth.

Zografakis et al. (2008) discovered that after delivering courses covering traditional energy, renewable energy, and energy conservation topics to students and parents, students developed a deeper understanding of these subjects (Zografakis et al., 2008). Yüksel (2019) delineated an educational framework for energy, which includes raising students' awareness of environmental and energy-related issues, imparting knowledge to differentiate between renewable and non-renewable energy sources, and empowering students to propose solutions to energy challenges in alignment with environmental and economic objectives of energy development (Yüksel, 2019). Hoffmann et al. (2023) conducted a study employing interactive virtual reality (VR) scenarios and explored whether factors related to energy supply security influenced participants' acceptance of green hydrogen (Hoffmann et al., 2023). This study underscores the efficacy of delivering energy knowledge through digital education. Through involvement in such research endeavors, the researchers aspire to inspire learners to actively engage in environmental stewardship and gain a deeper insight into the future of hydrogen energy.

3. Research Purposes

The primary objective of this study is to investigate the learning outcomes of learners engaging with the digital picture book "My Helpful Friend: Hydrogen" and their understanding of the topic of hydrogen energy. The study encompasses participants from high school to university levels. Through this research, a more comprehensive understanding of students'

learning outcomes related to hydrogen energy can be gained, providing valuable references and inspiration for future science education. As discussed above, the research purposes are as follows:

- (1) The Researchers create the science picture book "My Helpful Friend: Hydrogen" and examine the learning outcomes of cross-disciplinary learners in scientific concepts and reflections on their learning experiences.
- (2) The Research outcomes will provide recommendations for technology-assisted science teaching based on students' feedback.

4. Research Participants

We examined 11 students who had recently completed high school or vocational school and were preparing to begin their first year of university. These students were divided into two groups: 8 specialized in technical fields, while 3 specialized in sports. They were all candidates for a university's interdisciplinary bachelor's program, demonstrating proficiency in technical subjects and athletics. Despite having known each other for a week, they participated in our study. We used a questionnaire to assess their understanding of introductory chemistry and hydrogen-related knowledge. Our subsequent analysis will delve into how well they grasped these concepts.

5. Research Tools

5.1. Digital Picture Book

The goal is to guide students in learning through picture books, incorporating energy education with the theme of hydrogen energy. The scientific picture book "My Helpful Friend: Hydrogen" was created to enhance students' understanding of hydrogen energy through reading. Digital picture books are primarily used as a teaching method in this study, serving as essential teaching materials for the researchers. The educational problems the research tool addresses include enhancing understanding of hydrogen energy, stimulating interest in energy, and emphasizing the importance of sustainability issues.

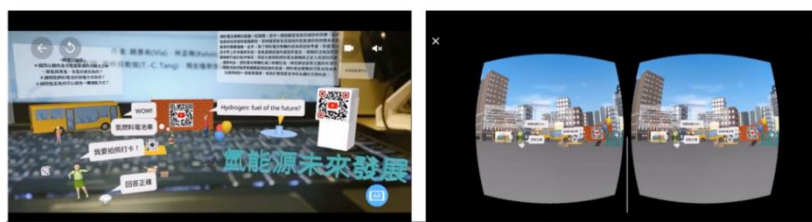


Figure 1 Picture Book Page Design

5.2. Digital Picture Book Script

Story Introduction: In a peaceful small town, an unexpected discovery leads to a magical journey about hydrogen energy. The residents stumble upon a metallic device left behind by a time traveler, changing the town's destiny and leading them toward a new future. Readers can personally engage in this marvelous adventure through this digital picture book.



Figure 2 Picture Book Cover Design



Figure 3 Hydrogen Energy VR Exhibition

6. Research Analysis

6.1. Test Analysis

The primary purpose of the test was to assess the participants' knowledge of hydrogen and hydrogen energy and to understand the effectiveness of the picture book through the pre-post comparison of the quasi-experimental research method. The SPSS analysis of the pre/post-test accuracy rates for all nine questions is shown in Table 1 below:

Table 1. *Pre-Post Test Analysis*

<u>Paired Sample</u>						
	<u>M</u>	<u>N</u>	<u>SD</u>			
<u>Pretest Accuracy</u>	<u>.54</u>	<u>9</u>	<u>.25</u>			
<u>Post-test Accuracy</u>	<u>.73</u>	<u>9</u>	<u>.22</u>			
<u>Paired Samples Correlations</u>						
	<u>N</u>	<u>correlation</u>	<u>p-value</u>			
<u>Pretest Accuracy</u>	<u>9</u>	<u>.82</u>	<u>.007</u>			
<u>& Post-test Accuracy</u>						
<u>Paired Sample T-test</u>						
	<u>M</u>	<u>SD</u>	<u>SE</u>	<u>t</u>	<u>df</u>	<u>p-value</u>
<u>Pretest</u>	<u>-.19</u>	<u>.14</u>	<u>4.05</u>	<u>-3.96</u>	<u>8</u>	<u>.004</u>

Accuracy

- Post-test

Accuracy

Paired Sample Effect Size

		<u>95% Confidence</u>			
		<u>Standardized</u>	<u>Point</u>	<u>Interval</u>	
				<u>Lower</u>	<u>Upper</u>
		<u>effect ^a</u>	<u>estimation</u>	<u>bound</u>	<u>bound</u>
<u>Pretest</u>	<u>Cohen's d</u>	<u>.14</u>	<u>-1.32</u>	<u>-2.22</u>	<u>-.39</u>
<u>Accuracy -</u>	<u>Hedges g</u>	<u>.15</u>	<u>-1.26</u>	<u>-2.11</u>	<u>-.37</u>
<u>Post-test</u>					
<u>Accuracy</u>					

Based on the analysis in Table 1, the study analyzed participants' performance on nine test items before and after reading the "My Helpful Friend: Hydrogen" science picture book. Before reading, the average accuracy rate before reading was 53.84%, while it increased to 72.71% after reading. The correlation between pretest and post-test scores was 0.82, indicating a strong association. Additionally, a paired sample t-test showed a significant difference in accuracy rates before and after reading, with a p-value of 0.004. This result suggests that participants' understanding of hydrogen energy significantly improved after reading the book. The analysis indicates a substantial enhancement in participants' knowledge levels following their engagement with "My Helpful Friend: Hydrogen."

6.2. Test Analysis

This study analyzed the questions according to their difficulty level and basic education level. They were divided into three main categories: (1) essential science education knowledge points, (2) scientific knowledge inference questions, and (3) popular science knowledge memory questions. In summary, the following analysis will focus on the difficulty level of each group of questions and the student's learning effectiveness.

6.2.1. Basic Science Education Knowledge Points

The primary science education knowledge point aims to assess whether students have basic general knowledge of science. The researchers designed these questions to ensure simplicity and clarity while avoiding misleading options. The questions were categorized as essential science knowledge points. They could be answered quickly and correctly if the participants had basic knowledge of sciences or received relevant daily information through family, school, or media. For instance, in the pretest, the accuracy rates for Questions 1 and 6

were 84.6% and 92.3%, respectively. This result suggests that participants may have learned relevant chemical knowledge in previous primary education or acquired information about green energy through news media. Therefore, participants could answer these questions correctly before reading the picture book, which aligns with the researchers' expectations.

The primary science education knowledge point is mainly about the basic knowledge of science that the participants should have. There are two questions in this question type, and the data are analyzed in Table 2.

Table 2. *Basic Science Education Knowledge Point*

Question number	Question	Pretest	Posttest	SD _{pretest}	SD _{posttest}	t
Question 1	1. What chemical element makes hydrogen gas?	82%	91%	23.36	15.08	-1.000
Question 6	6. Why is hydrogen called green energy?	91%	100%			

Students generally met the standard for this scientific knowledge when testing the essential science education knowledge points. Therefore, in the pretest, the average scores were above 80%, and after the post-test, the scores were above 90%. Thus, the test's purpose was to test whether students had basic knowledge of science, and 11 participants demonstrated ability in basic scientific knowledge. Therefore, there were no significant differences between the pretest and post-test scores.

6.2.2. *Scientific Knowledge Inference Questions*

The second category of questions requires extended thinking through one's science knowledge. These questions also deal with the properties of hydrogen and hydrogen energy, but the answers are not obvious and may not be directly mentioned in textbooks. Participants may have needed a senior high school level or higher education and a certain level of scientific knowledge to make informed choices. These questions are categorized as scientific inference questions. Results for questions like Questions 3 and 4 showed minimal improvement, likely because the answers were not directly provided in the picture book. Despite covering related topics, such as hydrogen sourcing and energy efficiency, participants had limited time for thorough consideration and discussion during the short testing period. Therefore, scores were not significantly different between the pretest and post-test for this question type. Detailed analysis is provided in Table 3.

Table 3. *Scientific Knowledge Inference Questions*

Question number	Question	Pretest	Posttest	SD _{pretest}	SD _{posttest}	t
Question 3	Which of the following materials can be used to produce hydrogen gas?	55%	55%	23.36	26.97	-0.803
Question 4	How does the energy produced from hydrogen compare to other fuels (coal, petroleum)?	18%	36%			

6.2.3. Popular Science Knowledge Memory Questions

The popular science knowledge memory questions assessed participants' understanding of the key concepts in the picture book's popular science content. These questions might have posed challenges for individuals unfamiliar with hydrogen energy. Researchers deliberately included misleading options in the questions to test participants' attentiveness. Since the relevant information was directly provided in the picture book, those who absorbed and retained the knowledge could accurately answer the questions in the post-test. Notably, Questions 2, 7, and 8 showed significant increases in accuracy, surpassing 30%, which can be attributed to the emphasis on precise knowledge transmission in the book and instructions. For example, participants correctly answered questions regarding hydrogen vehicles emitting only water (Question 2), the various sources of hydrogen (Question 7), and the operation of hydrogen fuel cells (Question 8). However, there was no significant improvement in accuracy for Questions 5 and 9. Despite being directly mentioned in the book, incorporating more scientific terms might have hindered immediate understanding, potentially leading to resistance to learning. Detailed analysis is provided in Table 4.

Table 4. *Popular Science Knowledge Memory Questions*

Question number	Question	Pretest	Posttest	SD _{pretest}	SD _{posttest}	t
Question 2	What are the emissions from hydrogen vehicles?	36%	64%	27.4	22.4	-3.180 *
Question 5	Which of the following industrial methods is for the production of	45%	64%			

	hydrogen gas?					
Question 7	The colors represent different hydrogen production options. What is the difference between green, black, and gray hydrogen?	73%	100%			
Question 8	How is electricity generated from hydrogen fuel cells?	45%	82%			
Question 9	Why is hydrogen used for energy storage?	55%	64%			

6.2.4. Analysis of All Pretest and Post-test Comparisons

The researchers used paired-sample t-tests to compare participants' scores before and after reading the scientific picture book "My Helpful Friend: Hydrogen." Since 13 participants completed the pretest and 11 completed the post-test, the analysis was conducted with a sample size of 11 participants. Table 7 displays the results. The mean difference between pretest and post-test scores for content related to the picture book was -25.46, with a p-value of .005 (less than .05), indicating a significant improvement in knowledge acquisition after reading the book. However, for primary and inference questions, the mean differences between pretest and post-test scores were both -9.09, with p-values greater than .05. This suggests no significant improvement in fundamental understanding and inference skills after reading the picture book.

7. Conclusion

This study investigates the learning outcomes of senior high school to university-level learners after engaging with the digital picture book "My Helpful Friend: Hydrogen" and studying hydrogen energy. The research seeks to inspire students' interest in science learning through "My Helpful Friend: Hydrogen" and delve into their performance and attitudes towards hydrogen energy knowledge. Through this study, a deeper understanding of students' learning in hydrogen energy can be gained, providing valuable insights and guidance for future science education. Based on the research objectives, this study draws the following conclusions:

- (1) The self-designed picture book "My Helpful Friend: Hydrogen" demonstrated significant learning effectiveness among cross-disciplinary learners. Reflections from

participants on their learning experiences indicated a positive impact of the picture book. This study suggests that "My Helpful Friend: Hydrogen" successfully stimulated students' interest in scientific concepts and provided positive feedback regarding their learning.

(2) Based on students' feedback, several recommendations for technology-assisted science teaching are proposed in this study: a. creating more self-learning picture books with scientific themes to enhance student's learning effectiveness and meaning and b. we are transforming complex scientific knowledge into picture book format through cross-disciplinary collaboration to improve students' learning outcomes.

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