

Optimizing Mobile-Assisted Inquiry Learning with Interactive Videos to Boost Scientific Explanation and Understanding of Seventh Graders [†]

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Abstract: Interactive videos and digital technology have been recognized by educators as supportive tools for learning science. To assess their impact, we compared seventh-grade students' abilities to explain scientific phenomena and understand climate change using interactive videos. Eighty-four students from a public secondary school participated in this research. They were divided into two groups, one using KKU iNote (EG1) and the other combining KKU iNote with interactive videos (EG2). Significant differences were observed in the scientific explanation scores between groups, with EG2 outperforming EG1. This suggested that interactive videos boosted students' competency in explaining scientific concepts. Moreover, both groups showed an improved understanding of climate change in post-learning, indicating the positive impact of inquiry-based learning. In particular, EG2 scored higher in their scientific understanding than EG1. This implied that integrating digital technology, particularly interactive videos, effectively enhanced students' scientific explanation and understanding during inquiry-based science learning.

Keywords: explanation; science; digital technology; secondary school



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1. Introduction

The rapid development of technology has led to the integration of various technologies into various aspects of daily human life. Simultaneously, education has also incorporated technology to enhance the learning skills of students. Digital technology-integrated teaching methods have been introduced to enhance learners' development. One notable approach is the incorporation of videos in knowledge presentation. Currently, the use of videos in education has increased to improve the efficiency of content delivery, which has proven to be more effective during learning than traditional textbooks [1]. In inquiry-based science learning, students actively participate in activities that involve practicing thinking, observing, analyzing, and presenting. This emphasizes the development of knowledge through the inquiry process. Teachers serve as facilitators, guiding, advising, and assisting students while also fostering collaborative learning. However, since inquiry-based science learning focuses on the process of knowledge acquisition and not on the development of scientific explanation skills, it may not address the development of student's abilities to explain scientific concepts. According to the National Research Council [2], the ability to explain scientifically indicates students' learning skills and fundamental understanding, impacting their engagement in inquiry-based science learning. This, in turn, leads students to understand science content [3,4].

A scientific explanation consists of claims, evidence, and reasoning, which support students in communicating their explanations and arguments. Moreover, the ability to

create scientific explanations of phenomena or processes in various scientifically observable forms based on information from research and linking to external experiences is important in developing students' science understanding. Science provides knowledge about phenomena and enhances our understanding of phenomena [5]. In developing students' scientific learning skills through investigation, the mobile application KKU iNote is used, an application designed to facilitate the creation of scientific explanations. In the present day, the utilization of digital technology holds a key position in education. Whether a researcher, an educator, or a science teacher, the emphasis lies in integrating digital technology, as a valuable instrument for fostering inquiry-based science learning, into the science classroom [6].

To reveal the impact of these technologies, we compared seventh-grade students' ability to explain phenomena scientifically and their understanding of climate change. We examined science inquiry-based learning using digital technology, explored the role of interactive videos in the learning process, and evaluated the impact of the mobile application KKU iNote. The findings of this study provide educators and science teachers with a reference to enhance their students' abilities to explain scientifically and understand using digital technology.

2. Literature Review

2.1. Scientific Explanation

The science standards published by the National Research Council [2,7] emphasize that scientific explanations are an essential feature, fundamental ability, and show an understanding of scientific inquiry. Students' explanations that contain flaws, such as citing irrelevant or insufficient data to support their claims, do not necessarily stem from an unscientific way of thinking. Instead, this is attributed to limited opportunities for scientific practices, wherein they can develop, argue, and evaluate explanations through their investigations [8]. Scientific explanations aid in evaluating students' grasp of scientific concepts and reasoning. In addition, the process of constructing such explanations can be used to develop their understanding of science and the scientific practice of explanations. The effectiveness of these scientific expositions can be assessed using targeted indicators to enhance their comprehension and knowledge of scientific principles. When appraising students' scientific commentary, their thinking abilities are stimulated [9]. Additionally, the evidence chosen by students is emphasized to incorporate their explanations into their perceptions of the current phenomenon, determine the relevance of their explanations, and recognize the data chosen [10].

2.2. Interactive Video

Interactive videos incorporate interactive elements and encourage viewers to respond and provide feedback on their responses [11]. Videos represent an enhanced form of digital content and are enriched with various features such as embedded questions, external content links, and additional instructional tools such as instant answers and user statistics for their monitoring. By incorporating extra content and ample guidance, they infuse interactivity into conventional lectures. Viewers engage with the material, participating as passive observers and active participants who answer questions, respond to comments, and access supplementary materials. Notably, video creators can track viewers' progress toward specific objectives by analyzing their data, including answers to questions, responses to comments, and detailed statistics on their viewing behavior. Through the integration of interactive elements, videos empower users to actively engage with the content and the video's creator and fellow viewers, enriching the learning experience. Interactive videos shift individuals from being passive observers to becoming active participants [12]. Additionally, they are utilized to encourage efficient learning. The ability to engage with features in interactive videos while watching them boosts motivation through making this an enjoyable experience [13,14].

3. Materials and Methods

In this quasi-experimental research, we employed a quantitative methodology and evaluated seventh-grade students' ability to articulate scientific explanations of climate change. We investigated the impact of interactive videos on the learning process. The students were divided into two groups: one utilizing KKU iNote (EG1) and the other combining KKU iNote with interactive videos generated by H5P (EG2) (Figure 1). We assessed the students' scientific understanding and their proficiency in grasping scientific concepts related to climate change.

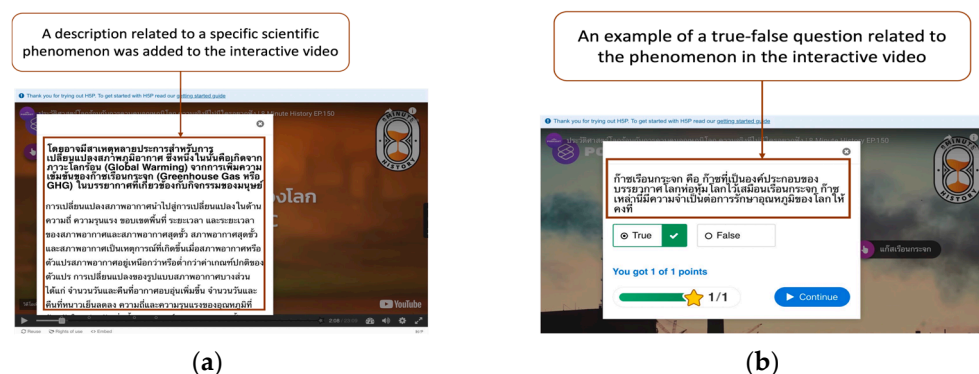


Figure 1. Interactive video generated by H5P: (a) text added to specific aspects of the video, (b) true-false question used for assessment.

3.1. Participants

Eighty-four students from a secondary public school in the northeast of Thailand were selected using a random sampling method. All students were in the seventh grade, with ages ranging from 12 to 13 years. They were divided into EG1 ($n = 42$) and EG2 ($n = 42$) and had no prior experience using KKU iNote and interactive videos.

3.2. Materials

Their scientific explanations were collected using the KKU iNote mobile application, which was developed by the Smart Learning Innovation Research Center at Khon Kaen University, Thailand, along with three probing questions. Each question consisted of claims, evidence, and reasoning. These were used to assess their ability to provide scientific explanations. The knowledge of global climate change (KGCC) instrument was designed to evaluate science methods used to enhance students' scientific understanding of climate change and their comprehension of the fundamental science behind understanding weather and climate phenomena and their concepts. The extended-response component was developed using constructive modeling based on four components: (1) the construct map, (2) item design, (3) the outcome space, and (4) the measurement model [15,16]. The KGCC comprises the greenhouse effect, the carbon cycle, the causes of climate change, and the consequences of climate change.

3.3. Methods

Both groups engaged in an inquiry-based learning process using KKU iNote in five stages: (1) engagement, (2) exploration, (3) explanation, (4) elaboration, and (5) evaluation. Each stage was designed to support students in addressing the three key components of scientific explanation. For EG1, the engagement stage was focused on sparking students' interest through targeted questions related to the topic, which were prepared by educators. These included sections for formulating claims in a short-answer format. In the exploration stage, students searched for information from resources to support their claim with evidence. In the explanation stage, students expressed their understanding, which was evaluated using the initial claim. A reasoning-focused short-answer question was posed at this stage. The elaboration stage involved a deeper analysis and discussion of the

information gathered, where students, in groups, synthesized their findings on chart paper. The evaluation stage allowed the students to present to the class and assess the knowledge they acquired through inquiry, fostering peer discussion about the learning process.

EG2 followed a similar learning process, which combined KKU iNote with interactive videos. In the engagement stage, interactive videos on global warming were shown, encouraging students to formulate claims relevant to the observed phenomena. Interactive features such as a drag and drop assessment and pop-up questions within the videos were used for evidence collection. The other stages followed the inquiry process adopted by EG1, integrating interactive media into learning (Figure 2). Traditional and multimedia resources were integrated to enhance the educational experience and promote an understanding of scientific concepts.



(a)



(b)



(c)

Figure 2. Student activities in class: (a) students exchanging their research knowledge with peers, (b) students answering questions in KKU iNote, and (c) students summarizing their knowledge and presenting to the class.

3.4. Data Collection and Analysis

We assessed the scientific explanations and understanding of 84 students in EG1 and EG2 who were using the KKU iNote in their science classes. In terms of their scientific explanation, the assessment framework included claims, evidence, and reasoning [9] on a 9-point scale (Table 1). In two sessions of 240 min, students responded to the inquiry questions and stated the three components of the learning process. The scientific understanding assessment was conducted using four extended-response items focusing on climate change, with each item worth 4 points. This scientific understanding test was performed for 40 min as a pre-test. Then, EG1 and EG2 were intervened. After completing the learning process, a 40 min post-test was used to measure the interventions' impact on their scientific understanding. The data were analyzed using the Mann–Whitney U test and the Wilcoxon signed-rank test to assess within-group changes pre- and post-intervention and evaluate between-group differences. SPSS was used to ensure the data's evaluation and interpretation were correct.

Table 1. The criteria for scoring the quality of scientific explanations.

Component	Level of Competency for Scientific Explanation		
	Level 0	Level 1	Level 2
Claim	Does not make a claim or makes an inaccurate claim.	Makes an accurate but incomplete claim, for example, “Caused by solar energy that reaches the atmosphere but cannot be reflected into space”.	Makes an accurate and complete claim, for example, “The world’s greenhouse effect caused by the Earth’s atmosphere being destroyed by CFC and blocking it, making it unable to reflect heat away global warming increases. It also receives radiation from the sun to increase the heat of the earth”.

Table 1. Cont.

Component	Level of Competency for Scientific Explanation		
	Level 0	Level 1	Level 2
Evidence	Does not provide evidence, or only provides inappropriate evidence (evidence that does not support the claim).	Provides appropriate, but insufficient, evidence to support the claim. May include some inappropriate evidence.	Provides appropriate and sufficient evidence to support the claim.
Reasoning	Does not provide reasoning, or only provides reasoning that does not link evidence to the claim.	Provides reasoning that links the claim and evidence. Repeats the evidence and/or includes some scientific principles, but not a sufficient amount.	Provides reasoning that links the evidence to their claim. Includes appropriate and sufficient principles.

4. Results

4.1. The Comparison of Scientific Explanation

We investigated the scientific explanation abilities of EG1 and EG2 to analyze their claims, evidence, and reasoning. Table 2 presents the results of the Mann–Whitney U-test. EG2 performed significantly better than EG1 in making claims, with a Z-score of -2.526 ($p = 0.012$), and reasoning, with a Z-score of -6.426 ($p < 0.001$), indicating their more effective skills in these areas. However, there was no significant difference in the evidence component. These results highlighted EG2's capabilities in key aspects of scientific explanation, while both groups demonstrated comparable abilities in providing evidence.

Table 2. The result of analyzing students' scientific explanations by Mann–Whitney U-test.

Component	Group (n = 42)	Mean Rank	Mean	Standard Deviation	Z	p-Value
Claim	EG1	36.25	2.98	0.91	-2.526	0.012 *
	EG2	48.75	3.43	0.62		
Evidence	EG1	41.00	3.83	0.69	-0.615	0.538
	EG2	41.00	3.93	0.69		
Reasoning	EG1	26.99	2.02	0.80	-6.426	<0.001 *
	EG2	58.01	3.19	0.45		

* $p < 0.05$.

4.2. The Comparison of Scientific Understanding

We assessed the scientific understanding of EG1 and EG2 using pre- and post-tests. The descriptive statistics of both tests are presented in Table 3. For the pre-test, EG1 had a mean score of 3.81 (SD = 1.11) and EG2 had a mean score of 3.02 (SD = 1.30). After the intervention, there was a significant increase in the scores, with EG1 illustrating a mean of 6.14 (SD = 1.69) and EG2 a mean of 7.40 (SD = 1.84) in the post-test.

Table 3. Descriptive statistics of students' scientific understanding.

Component	Group	n	Mean	Standard Deviation
Pre-test	EG1	42	3.81	1.11
	EG2	42	3.02	1.30
Post-test	EG1	42	6.14	1.69
	EG2	42	7.40	1.84

To analyze the significance of the observed differences, a Wilcoxon signed-rank test was conducted for each group. The results indicated significant increases in scientific understanding for both groups (Table 4). EG1 showed an improvement, with a Z-score

of -5.126 ($p < 0.000$), and EG2 demonstrated a more significant increase, with a Z-score of -5.677 ($p < 0.000$). Both groups significantly enhanced their scientific understanding post-intervention. The larger increase in EG2's scores suggested there were differences in the effectiveness of the incorporation of the interactive videos and KKU iNote.

Table 4. Wilcoxon signed-rank test results of the pre–post-test science understanding of the two groups.

Group (n = 42)	Pre-Test		Post-Test		Z	p-Values
	Mean	Standard Deviation	Mean	Standard Deviation		
EG1	3.81	1.11	6.14	1.69	-5.126	$<0.000^*$
EG2	3.02	1.30	7.40	1.84	-5.677	$<0.000^*$

* $p < 0.05$.

5. Discussion and Conclusions

5.1. Scientific Explanation

This study was carried out to enhance students' abilities to construct scientific explanations specifically related to climate change. The participants constructed scientific explanations of this topic. Several participants struggled with specific concepts such as the greenhouse effect. A notable inconsistency was observed in their understanding of chlorofluorocarbons (CFCs) and their impact on the greenhouse effect. Prior research indicated that misconceptions or alternative conceptions about the greenhouse effect and global warming persisted among secondary school students even after the educational interventions [17]. Moreover, the participants displayed limitations in developing scientific explanations of different components. For instance, their responses often lacked detail in certain areas due to an inaccurate understanding of climate change content. Their ability to effectively link evidence with claims was consequently lacking. The lowest performance was noted in reasoning, where students frequently confused claims with reasons due to unclear distinctions between these elements. The results coincided with those of previous studies. Yu and Lin [18] found that proficiency in creating scientific explanations followed a solid understanding of science, with reasoning consistently scoring the lowest. Lertdechapat [19] discussed how the absence of precise scientific knowledge affected the quality of explanations, leading to incomplete reasoning and inadequate links between claims and evidence. Such results illustrated the need for effective educational strategies that promote scientific explanation skills through scenarios that are combined with students' everyday experiences [20]. EG2 scored higher in both scientific explanation and understanding, emphasizing the impact of constructing scientific explanations on enhancing scientific knowledge [9]. Additionally, EG2's performance in all components was attributed to the integration of interactive video-based learning, which incorporated argumentation and inductive questioning to help students explore hypotheses, build explanations, and expand their understanding [21].

5.2. Scientific Understanding

Inquiry-based learning with digital technology and interactive videos was used to enhance the learning experience in science. This encouraged students to actively inquire about scientific explanations and deepen their scientific understanding [22]. Significant enhancements were observed in both groups in the post-test compared to their pre-tests. This indicated that the incorporation of interactive videos and KKU iNote into inquiry-based learning potentially enhanced its effectiveness. The interactive videos included links. These links were used by the participants to explore related topics from other resources used in their learning. When the video was paused, students contemplated the learning subject extensively and discussed it with classmates. Additionally, they responded to pop-up questions that guided their focus and comprehension [21]. In addition, this

interactivity affected the effectiveness of education [23]. Interactivity within educational settings strengthens students' understanding of learning concepts [24]. Daily [25] found that the use of multiple media enriched learning through enhanced visualization and improved learning outcomes. We discovered a significant feature of integrating digital technologies into an inquiry-based learning approach. Students' intrinsic motivation and self-determination increased when using technologies in class [26].

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