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The Effect of Inquiry-Based Concept Cartoon on Biology Conceptual Understanding

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Abstract

Cartoons appear to be an important teaching strategy, with numerous benefits in science classrooms. However, they have received little attention in Thai education as well as in biology concepts. The purpose of this research is to compare the conceptual understanding of biology of 30 freshmen pre-service teachers studying at the Faculty of Education, Rajabhat University, who registered a bioscience course in the second semester of the 2020 academic year by using four 5E lesson plans with biology concept cartoons:1. Cell transportation (4 h/week), 2. genetics (4 h/week), and 3. Ecosystems (4 h per week), 4. Evolution (4 h a week): 16 items of the two-tier multiple-choice test. The results showed that the biology concept cartoon lesson had a significant difference in academic achievement score, which was significantly higher than the pre-test scores ($p < .05$).

Keywords: Concept Cartoon, 5E, Biology conceptual understanding

1. Introduction

In the world of big data, a lot of information is readily available. For students to live in rapidly changing world, a 21st century education needs to give them the essential skills such as critical thinking, creativity, collaboration and communication. In order to support future learners, the learning process becomes more meaningful as it prioritized authentic experience of students, made students become active learner. Frossard, Barajas and Trifonova (2012) suggested that using different teaching methods and techniques such as diagrams, mappings, games and cartoons with the context of students' dairy life can raise children's interests and attention. In addition, it can motivate and inspire students actively learning (Sithsungnoen, 2018).

One of the learning approaches that enable students' active participation in science teaching is 5E Instructional Model. It was developed in the mid-1980s by Biological Sciences Curriculum Study (BSCS) and introduced to Thailand by The Institute for the Promotion of Teaching Science and Technology (IPST) since 1972. The phases of the 5E learning cycle consists of engagement, exploration, explanation, elaboration, and evaluation (Bybee et al., 2006). It effects on conceptual understanding development and cognitive strategy used in solving problems (NRC, 2000). 5E learning cycle process can increase students learning motivation, conceptual understanding and scientific process skills (Şahin et al., 2017; Türkoguz, 2014).

Instruction aided with concept cartoons are one another approach that can promote active participation of students and frequently used in science education (Morris et al., 2007). They are visual materials composed of cartoon characters discussing real life issues by offering different perspectives (Muamber, 2020). Concept cartoons were developed in 1992 by Brenda Keogh and Stuart Naylor based on the constructivist approach. They were created to meet in-service teachers' needs of finding new instructional methods in science education (Mark and Hendrika, 2011). Concept cartoons can be used in 5E teaching model for revealing misconceptions and improving conceptual understandings, scientific process skills and active questioning. (Stephenson et al, 2002; Keogh and Naylor, 2000; Şahin et al., 2017; Türkoguz, 2014). In addition, it can improve the pre-service teachers' perspective regarding the teaching strategies that can be considered in their professional preparation (Gunning and Mensah, 2010; Keogh and Naylor, 2000).

In previous publication we found that concept cartoons seem to be an important teaching strategy which show a lot of the benefits in science classroom. However, they have been studied rarely in Thai education and also in biology concept. Therefore, the aims of this study are to analyze the effect of 5E teaching model combined with concept cartoons on freshmen pre-service teachers conceptual understanding and their attitude towards this instruction.

2. Theoretical Review

2.1 5E teaching model

In their 2014 study, Türkoguz and CN examined the impact of the 5E learning cycle and argumentation-based concept cartoon activities on students' understanding of the scientific method. These exercises were modified for the science and technology course's "Electricity in Our Life" unit using a semi-experimental design that included a control group and pre- and post-tests. The participants were seventh graders from an Izmir, Turkey public school in 2012–2013. Random selection was used to select the experimental group (n=28) and the control group (n=26). The Science Process Skills Scale, which has 28 items, was used to collect data. This scale covers abilities including observation, categorization, measurement, prediction, inference, hypothesis-forming, variable identification, control and replacement, experiment design, data saving, data processing and modelling, reporting results, and interpretation. The findings demonstrated that students in the experimental group significantly outperformed those in the control group in the development of science process skills for the "Electricity in Our Life" unit.

Ahin et al. (2017) examined how the 5E teaching paradigm affects pre-service primary school teachers (PSPTs). 90 PSPT students in their second year at a state institution made up the sample for this study. A single research group conducted the study using a pre-experimental methodology. The study's data were gathered using concept cartoons that featured astronomy concepts such as the sun, stars, planets, meteors, solar systems, and constellations. During the eight course hours, the teaching materials developed for the selected astronomy concepts were used. Most PSPTs were found to have alternate conceptions. When PSPT pre-and post-test scores were compared, a sizable decline was observed. It was discovered that conceptual change benefited from learning based on the 5E teaching approach. It is possible to say that the 5E teaching paradigm has been successful in addressing alternate concepts.

Yakob et al. (2020) examined how well pre-service teachers understood the idea of meiosis using the linked inquiry5E approach. One group participated in the study, which had a

pre-test, post-test, and a delayed post-test. 31 future instructors from a public university participated in this study. The Meiosis Conceptual Test, a tool with 19 items, was used. One-way repeated-measures Measure ANOVA was used to analyze the data. The results demonstrated that this effect was statistically significant.

2.2 Concept Cartoon

In an effort to build a creative teaching and learning technique that considers constructivist views on learning in science, Keogh and Naylor (1999) produced concept cartoons. These statistics were based on 149 teaching sessions. 51 teachers, 85 primary student teachers, and 2 students in the primary and secondary age ranges served as data sources. These statistics were based on 149 teaching sessions. Interviews, questionnaires, and two case studies served as data collection methods. According to the findings of an evaluation of the use of concept cartoons, teachers and students responded to the cartoons in a generally positive way.

In order to evaluate the quality of the arguments produced in six groups of eight grade and nine students over the course of the research, Webb et al. (2008) used a modified five-point Toulmin's Argumentation Programme (TAP) instrument with two classes of South African students in the ninth grade (eight weeks). They discovered that discussions in class were scarce and, when they did occur, were rarely above the lowest point on the study's five-point argumentation scale. Over a six-week period, the children watched three additional concept cartoons. The sparse data gathered indicates that there is potential for employing concept cartoons to spark debate and advance learners' thinking. Cartoons with writing frames help students develop their thinking.

Birisci et al. (2010) investigated pre-service elementary teachers' views on concept cartoons using a mixed research method with 40 freshmen students enrolled in an Elementary Teaching department at a small university in northeastern Turkey in the spring of 2008. The results suggest that using concept cartoons in instruction rescues students from boring traditional lecturing, helps teachers improve their instruction and align it with constructivist learning theory, makes the lecture more interesting and entertaining, and makes students more active, creating a discussion environment where students can improve their critical thinking skills and positively influence students' attitudes towards the lesson in particular and school in general and may have an important role in improving students' academic achievement.

Chin et al. (2010) used a concept cartoon and students' drawings and talks to identify students' ideas about biological inheritance. They then created scaffolding structures that could be used in conjunction with the concept cartoon to help students articulate their ideas on concepts related to inheritance. Students in Singapore's primary 5 class (aged 10 to 11) collaborated in small groups to discuss the conflicting viewpoints put forth by the cartoon's characters. The use of scaffolding tools helped direct class discussions and motivated students to analyze, refute, and record their own and their classmates' viewpoints. Students' inquiries and claims had formative potential, as they drew on each other's ideas, and via their oral and written discourse, they were able to identify a number of alternative perspectives. By creating a formative learning environment, the teacher was able to actively involve students in learning while also monitoring their thinking.

Zion et al. (2015) examined how students conceptualized homeostasis, a basic biological concept. Process dynamics, physiological balance, control and regulation, feedback mechanism, environments, dependencies between events inside a system or process, multisystems, and levels of organization were the eight qualities they defined. 93 biology majors in their 12th grade studied the homeostasis characteristics. A study of students'

responses indicated a wide range of false views, in addition to their accurate scientific judgments of the qualities of homeostasis. The findings revealed that teachers may be able to detect their students' conceptual knowledge of homeostasis by breaking down scientific principles into their constituent qualities.

Engül et al. (2017) assessed how the concept of cartoon-integrated worksheets affected the conceptual comprehension of Newton's Laws of Motion in grade 9 students. The sample consisted of 102 grade 9 students (aged 15–16 years) enrolled in an Anatolian High School for a quasi-experimental study with a control group. The experimental group (52 students) and the control group were randomly assigned (50 students). Newton's Laws of Motion Test (NLMT) and Interview about Instances (IAI) were used to collect data. The outcomes demonstrated that the experimental group outperformed the control group.

The impact of concept cartoons on 7th grade students' understanding of the ideas in the chapter "The Structure and Properties of Matter" was examined by SAY et al. (2018). The themes in the unit included students' preconceptions and ideas. The Structure and Properties of Matter's Concept Test (SPMCT) and semi-structured interviews were used to gather research data. 49 pupils in grade 7 made up the research's total sample; 24 were in the experimental group and 25 were in the control group. As a pre-test, the SPMCT was created by taking into account alternative conceptions discovered through the results of the literature analysis. The lesson on "the structure and properties of matter" was then studied along with concept cartoons that had been developed. The SPMCT was administered to the students as a post-test at the conclusion of the study. The findings showed that students' ideas on the topic under study were diverse, and some of them possessed a basic understanding of the structure and properties of matter, but were unable to apply it. To promote the test results, randomly selected students from the experimental group were interviewed. After examining the test and interviews, it was determined that the application reduced the students' prior alternative ideas of the matter's structure and properties, did not reveal any further alternative conceptions, and yielded accurate results.

Elif Ertem and Esra Klç (2019) used a case study method for their research, which is based on a qualitative approach. Forty eighth-graders (25 girls and 16 boys) from two distinct classrooms at a public high school in Eastern Anatolia, Turkey participated in the study. In this study, the application procedure took place over the course of one week, and the interviews that were conducted afterward lasted three days. A semi-structured five-item interview form was used to gather the data. The study's findings showed that the idea of cartoon activities gave pupils a wide range of advantages (instructive, entertaining, motivating, mental growth, etc.) and that students had favorable opinions about their use in lessons.

A module for the integration of concept cartoons into the problem-based learning (PBL) approach in science lessons was provided by Kaçar et al. in 2020. Concept cartoons based on scenarios that deal with real-world issues were created as part of this study. These concept cartoons were used to create a module. The module was used in nine different classrooms at nine different schools and covered the subject of "heat insulation" as part of the science curriculum's "matter and heat" unit for sixth graders. The opinions of the students (n=27) regarding the module were ascertained using semi-structured interviews. The students said that the activities helped them recall their prior knowledge, made it easier for them to connect science to everyday life, and helped them learn material about heat insulation in a meaningful way.

3. Methodology Of Research

A mixed method design is chosen for the generation of both quantitative and qualitative data. Independent variable is 5E lesson plan with biology concept cartoon and dependent variables are conceptual understanding and attitude towards concept cartoon. Conceptual understanding is measured by using 16 items of two-tier multiple choice test and 4 items essay of biology concept cartoons test. In addition, attitude towards concept cartoon is measured by questionnaire and interview.

4.1 Research model

4.1.1 Conceptual understanding is based on a pre-experimental model with one-group pretest and posttest design.

O_1 ———— X ———— O_2
O_1 = Pretest
O_2 = Posttest
X = Inquiry-based concept cartoon on biology

4.1.2 Attitude towards concept cartoon is based on a pre-experimental model with one-group posttest design.

X ———— O_2
O_2 = Posttest
X = Inquiry-based concept cartoon on biology

4.2 The participants

The study group consisted of 30 participants of freshmen pre-service teachers studying at faculty of education, Rajabhat university who registered bioscience course in the second semester of 2020 academic year. They are taught with the inquiry-based concept cartoon on biology instruction during 16 h (4 h a week) for four weeks.

4.3 The instruments

The research instruments consist of

4.3.1 Four 5E lesson plans with biology concept cartoon includes;
- Week 1: Cell transportation (4 h a week)
- Week 2: Genetics (4 h a week)
- Week 3: Ecosystem (4 h a week)
- Week 4: Evolution (4 h a week)

4.3.2 The biology conceptual understanding test. (16 items of two-tier multiple choice test and 4 items essay of biology concept cartoons test)

4.3.3 The ten items of attitude towards concept cartoon questionnaire.

4.3.4 The semi-structure interviews.

4.4 The development of instruments

4.4.1 Concept Cartoons

Concept cartoons can be developed in several factors in everyday event by cartoon characters, which the text in bubbles included of biology concept. These concept cartoons support information of conflicts which lead students discuss and argument to encourage scientific thinking. This way they try to promote their own opinion to explain of observed phenomenon. For creating each concept cartoons, friendly design cartoon characters are used with everyday contexts that students are familiar. They include one main biology concept and

four alternative statements which share the biology scientifically acceptable viewpoint. Then they are presented to the experts in biology teachers and educators. The feedback received from the experts are improved in accordance with the reviews. After that the concept cartoon is included in the 5E lesson plan. Concept cartoons are assigned to students on a worksheet during the class with common questions: which characters do you strongly agree with and why? Students work on worksheets individually, approximately 60 minutes.

4.4.2 Four 5E lesson plans with biology concept cartoon includes:
1. Cell transportation (4 h a week)
2. Genetics (4 h a week)
3. Ecosystem (4 h a week)
4. Evolution (4 h a week)
4.4.3 The biology conceptual understanding test
There are two parts of the pre and post test:
Part I: 16 items of two-tier multiple choice test.

Each item consisted of two tiers, the first tier is biology knowledge and consists of questions with four answer choices of which had one correct answer. The second tier is the reason for the answer in the first tier that has been chosen and consists of questions with four answer choices which had one correct concept answer and three distracters reflect students' misconceptions. The first tier correct answer was scored as 1, the second tier correct answer was scored as 1 if the first tier item was wrong then the second tier item was scored as 0 point. (adapted from Taşlidere (2013) and) So the maximum score students could get from this test is 32.

Part II: 4 items essay of biology concept cartoons test.

Each item was designed in 4 topics as follow: cell transportation, genetics, ecosystem and evolution. Then presented to the experts in biology teachers or educators. The feedback received from the experts are improved in accordance with the reviews. After that the tests applied to group experiment.

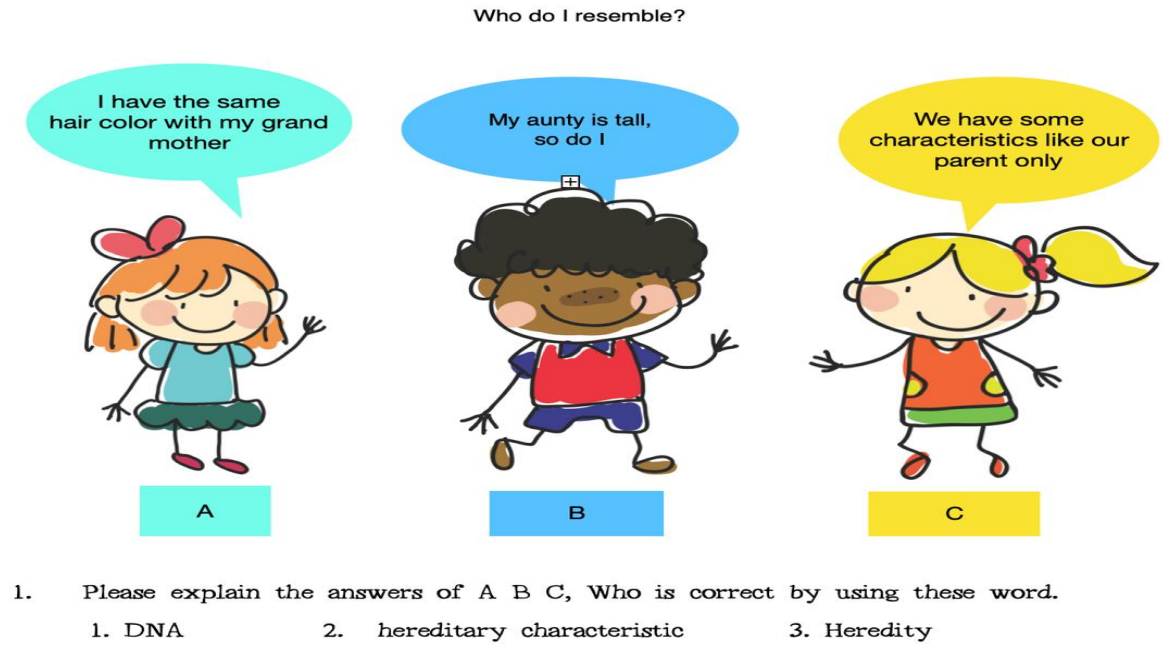

Figure 1. *Example of biology concept cartoon*

4.4.4 The ten items of attitude towards concept cartoon questionnaire

The 5-point Likert-type scale of 10 items composed of the questions about attitude toward concept cartoon in biology instruction adapted from Birisci, et al (2010). Then presented to the experts in biology teachers or educators. The feedback received from the experts are improved in accordance with the reviews. After that the questionnaire applied to experiment group. And 3 open-ended questions below.

1. Do you think that the lessons included concept cartoon had an effect on your learning?
2. What do you think about the tasks included concept cartoon?
3. How would you compare narrative lesson and concept cartoon lesson?

4.4.5 The semi-structured interview.

Five main open-ended questions were used during the interviews; however, participants were also asked probing questions when it was necessary adapted form Elif Ertem and Esra Kılıç (2019). As follows:

1. Have you ever seen concept cartoon activities before?
Code: Yes and No
2. What did you think when you first saw the concept of cartoon activities in biology?
Code: Interest/Attention, Entertain, how will we perform the activity?
3. What features of the concept of cartoon activities influenced you the most? What did you find most interesting about them?
Code: Colourful, Familiar, easily understanding,
4. What are your views on the use of concept cartoon activities in the course of biology?
Code: Fun, rerated to dairy life,
5. Would you use concept cartoon activities for teaching in the future? Why?
Code: Yes and No: motivating, entertaining, confusing.

4.5 Data collection

30 participants of freshmen pre-service teachers studying at faculty of education, Rajabhat university who registered bioscience course in the second semester of 2020 academic year were implemented with 5E with concept cartoon 4 h a week:

Week 1: Cell transportation
Week 2: Genetics
Week 3: Ecosystem
Week 4: Evolution

4.5.1 The biology conceptual understanding test

There are two parts of the pre and post-test: part I with16 items of two-tier multiple choice test each item consisted of two items and part II with 4 items essay of biology concept cartoons test were implemented in pre and post test of the experiment.

4.5.2 The attitude towards concept cartoon questionnaire

The 5-point Likert-type scale of 10 items questionnaire adapted from Birisci, S et. al (2010). were implemented in the end of the experiment which include the views on the advantages and disadvantages of concept cartoons (item No.1-5) and the views on using concept cartoons in professional teaching (item No.6-10)

Table 1. *The 5-point Likert-type scale of 10 items questionnaire*

No.	Items	Strongly agree (5)	Agree (4)	Undecided (3)	Disagree (2)	Strongly Disagree (1)
1	Concept cartoon make science lesson more pleasant.					
2	Concept cartoon make me confuse.					
3	Concept cartoons help me see my misconceptions.					
4	Concept cartoons in instruction is a waste of time.					
5	Concept cartoons help in bringing out students' prior knowledge on the topic					
6	I think designing appropriate situation for the topics is very difficult.					
7	I think characters' conservation difficult to create.					
8	I will use concept cartoons to attract students' attention.					
9	I will use concept cartoons to make students more actively involved in the lesson.					
10	I will use concept cartoon to my professional teaching.					

4.5.3 The semi-structure interview.

Five main open-ended questions were separated individual interviews conducted by 30 of the participants with the five main questions were as follows:

1. Have you ever witnessed the concept cartoon activities? Yes and No codes
2. What were your initial thoughts when you first saw the concept of cartoon activities being used to teach biology? Interest/attention, Entertaining,
3. What aspects of the concept of cartoon activities influenced you the most? What piqued your interest the most about them? Colourful, familiar, and simple to understand code
4. What are your thoughts on the use of concept cartoons in biology classes? Fun, rerated to dairy life code
5. Would you use concept cartoon activities for teaching in the future? Why? Yes and No: Motivating, entertaining, and confusing.

4.6 Data analysis

4.6.1 The effectiveness (E.I.) and efficiency (E1/E2) of the Inquiry-based Concept Cartoon approach E1 is calculated as a percentage of the average of all scores earned by students from their activities. E2 was calculated as the percentage of the average of all scores earned by students in their post-test. 1973 (Brahmawong) The effectiveness index (E.I.) was computed using pre-test and post-test scores.

4.6.2 Part I test Pre-Post Conceptual understanding tests

A paired sample t-test was used to examine differences in conceptual understanding between the pre-test and post-test data

4.6.3 The conceptual understanding evaluation in the part II test

The conceptual understanding in the part II test of 1 items essay of biology concept cartoons is divided into five categories adapted form by Westbrook and Marek, 1991 as following in table 2

Table 2. *The criteria of conceptual understanding*

Group of conceptual understanding	Explanations	score
Complete understanding : CU	The student's response parallels a theoretical, scientific view of the concept.	3
Partial understanding : PU	The student's response contains part, but not all, of the information necessary to convey either complete or sound understanding. No incorrect information occurs in the response.	2
Partial understanding with specific misconception : PS	The student's response contains correct information, but also indicates a misunderstanding concerning some aspect of the concept.	1
Specific misconception : SM	The student's response indicates a complete misunderstanding of the concept.	0
No Conceptual Understanding: NU	The student'sresponseconsistsof "I don't know," the question repeated, or irrelevant remarks, the page left blank.	0

Results And Discussion

1. The efficiency (E1/E2) and effectiveness (E.I.) of biology concept cartoon lesson

E1 is calculated as the percentage of the average of all scores earned by students from their activities. E2 is calculated as a percentage of the average of all scores earned by students on their post-test.

The effectiveness index (E.I.) was calculated by combining the pre-test and post-test scores.

. The E.I. is thus computed as follows:

E.I. = [(P2 – P1) / (100-P1)] * 100
E.I. = The effectiveness index
P1 = Pretest score
P2 = Posttest score

2. The academic achievement score.

-The pre-test and post-test mean, percentage, and standard deviation were computed.
-For dependent samples, pre-test and post-test scores were analysed using a t-test.
-The normalized gain <g> of the pre-test and post-test was examined and classified into three levels (Hake, 1998).

The efficiency (E1/E2) and effectiveness (E.I.) of biology concept cartoon lesson.

The efficiency of E1/E2 was 75.67/92.35, which was higher than the criteria of 80/80. The result of the effectiveness index (E.I.) was 0.85, which is higher than the criterion. The normalized gain was calculated according to Hake (1998). The results of the analysis are shown in Fig. 2.

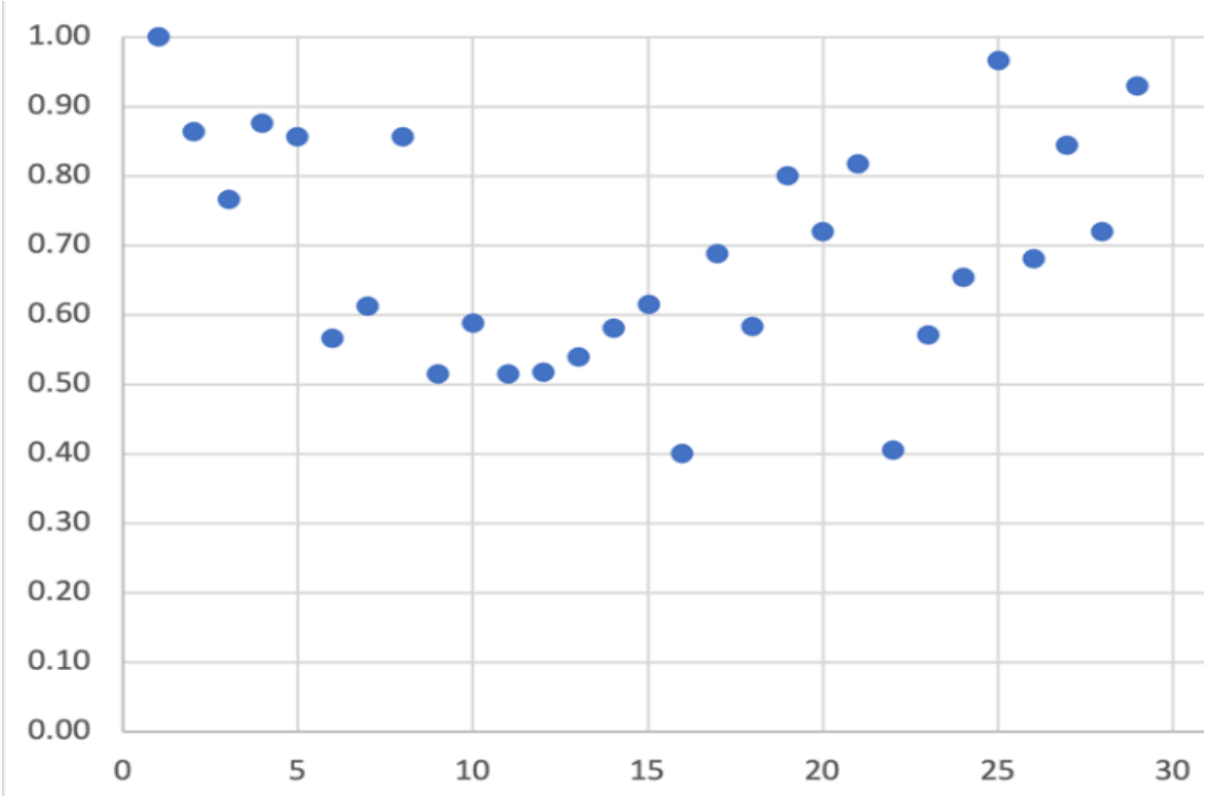

Figure 2 *Normalized gain index of biology concept cartoon lesson results.*

The academic achievement score result.

Figure 3 depicts the analysis's pretest and posttest results.

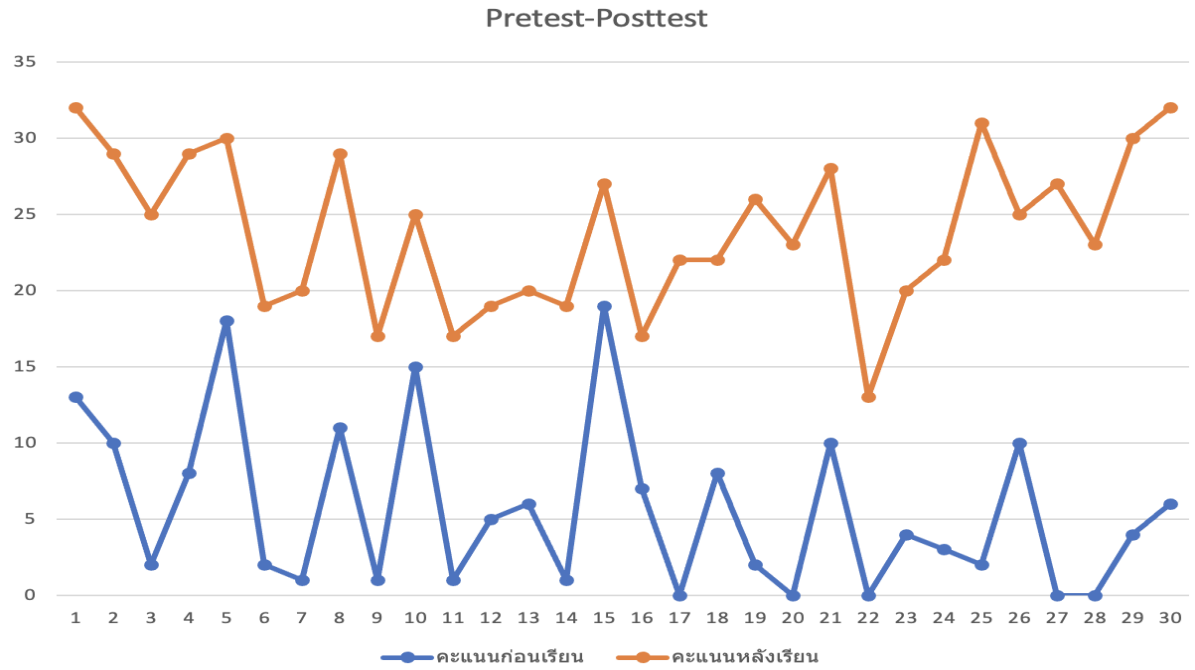

Figure 3 *The percentage score of pretest and posttest of academic achievement*

An independent t-test was used to determine the significance of the mean score difference between the pre-test and post-test scores. Table 3 presents the results of the analysis.

Table 3 *Analysis of dependent t-test regrading students' academic achievement test.*

	n	$\bar{x}$	S.D.	t	p	df
pretest	30	5.63	5.518	18.30	.000	29
posttest	30	23.93	5.152			

p> .05

As shown in Table 3, there was a statistically significant difference in pre- and post-application academic achievement between the experimental group students (t = 18.30, p.05). Before the application, the average academic achievement score of the experimental group students was $\bar{X}$=5.63, increasing to $\bar{X}$=23.93 after the application. The outcomes of this study demonstrate that cartoon lessons have a significant impact on students' academic achievement.

According to the constructivist approach, because students must actively participate in the process of information structuring, it is critical to use visual tools that can engage students in the lesson, create discussion environments, and allow them to learn more meaningfully. Biological concepts, many of which are abstract and difficult to learn, should be learned in an effective, meaningful, and permanent way in biology teaching, and new methods should be used by moving away from traditional methods to prevent mislearning. According to recent studies, cartoons can be used as visual education material in student-centered education using a constructivist learning approach. Furthermore, cartoons can be designed as materials that can be used to teach concepts to students in an enjoyable manner. Concept cartoons are a visual tool that can be prepared and used in biology education based on the constructivist approach to create permanent learning by ensuring active participation of students in the course during the learning and teaching process. According to previous studies, students' opinions on the use of concept cartoons were positive, and concept cartoons increased students' understanding and interest in the lessons. Researchers have discovered that cartoons positively affect students' academic achievement and make a significant difference. Learning occurs because of mental participation. Learning does not occur simply by storing information in a student's brain using the narrative method. Teachers who employ only one method or technique may not be successful. Teachers should use materials and tools that attract attention, ensure active student participation in the lesson, and appeal to the students' many senses as much as possible, such as slide pictures, concept maps, and concept cartoons. The attitudes of pre-service teachers toward the use of cartoons in their worksheets revealed that the analysis findings of teacher candidates' attitudes that cartoons have an effect on learning, create permanent knowledge, create an environment for curiosity, thinking, research, and discussion; provide motivation; and are entertaining and instructive.

Conclusion

The study group consisted of 30 freshmen pre-service teachers studying at Rajabhat University's Faculty of Education, who registered for a bioscience course in the second semester of the 2020 academic year. For four weeks, they were taught with an inquiry-based concept cartoon on biology for 16 hours (4 hours per week). The results demonstrated that a biology concept cartoon lesson had a significant difference in students' academic achievement scores in both the pre-test and post-test.

1. Conflict of Interest

The authors have no conflicts of interest to declare.

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